psa JOURNAL SECTION b

PHOTOGRAPHIC SCIENCE AND TECHNIQUE

A quarterly technical supplement to PSA Journal

TABLE OF CONTENTS—DECEMBER 1952

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EDITORIAL NOTES

Photography in Engineering and Science was the theme of a Technical Division Symposium at the 1952 National Convention in New York City in August. Because of the great interest that was evidenced, at the Symposium and afterward, the editors of PHOTOGRAPHIC SCIENCE AND TECHNIQUE have been asked to present as many of the papers as possible in this Symposium Issue.

Two papers from the Symposium had already been published in the October issue. Others will follow during 1953. The papers gathered together here tell a story of photography at work; digging out the secrets of mechanical operations, making time stand still or altering its pace, metering the unmeasurable, recording data for engineering use.

One of our authors, Joseph Tholl, the Cleveland authority on questioned documents, didn't know when he spoke at the 1952 Convention about the use of photography in his work that a representative of the government of Israel was in the audience. Afterwards Mr. Tholl learned he had been selected to teach document identification techniques to a photographer who will set up a laboratory in the new state of Israel for the photographic examination of questioned documents.

At the moment, according to the Cleveland Press, Mr. Tholl is busy ferreting out fraudulent X marks for his local election board from thousands of questioned ballots. Three indictments have already been returned by the Grand Jury as a result of this work and more are expected.

Our report from Stockholm on color photography processes currently available in Europe, by Dr. Heinz Gordon of the Swedish Colorphoto Corporation, seems to have been well received. Several readers of the October issue have expressed their appreciation for the publication in America of authoritative information on this subject that is so important in Europe and so little known here.

The second part of Dr. Gordon's paper, presenting the characteristics of the positive color print materials and their processing, was promised to appear in the next issue. It had to be postponed when this became our Symposium Issue for the Photography in Engineering and Science theme. The concluding exposition of European color print materials will appear in the February 1953 issue instead.

An index to technical literature in the field of photography is almost as necessary to the technical man in quest of information as the literature itself. This final issue of volume 18B contains a complete index of the papers published during the year.

PHOTOGRAPHIC SCIENCE AND TECHNIQUE is page-numbered separately from Section A of the PSA JOURNAL with the original intent that many readers would wish to bind the four quarterly issues that constitute a volume. A title page for Volume 18B is provided, along with the volume Index, for that purpose.

The general need for engineering data useful in the design and construction of photographic laboratories has been emphasized in a letter to the editor by Rodger J. Ross written from Bogota, Colombia where he is serving with the Canadian government's Technical Mission. "This is a large scale photographic operation," writes Mr. Ross, "the production of certificates of citizenship by means of photography."

It is a fundamental aim of PHOTOGRAPHIC SCIENCE AND TECHNIQUE to provide a nucleus for the development of a photographic literature that will serve the need to which Mr. Ross refers. In three full years of publication completed with this issue, we have built about that nucleus a core of authoritative information concerning technical aspects of photography. More papers dealing with specific engineering concerns in photography are scheduled for publication next year.

One of the most helpful contributions is likely to be the 1952 National Convention paper by L. E. Muehler and J. I. Crabtree, FPSA, "Materials of Construction for Photographic Processing Equipment." This paper deals with older materials as well as the new developments in stainless alloys together with plastic and other non-metallic materials. Resistivity to corrosion as well as comments on fabrication and maintenance will be described.

P. A.

FOURTH 1952 ISSUE ☆ VOLUME 18B, NUMBER FOUR ☆ PUBLISHED WITH THE PSA JOURNAL FOR DECEMBER 1952

PHOTOGRAPHIC SCIENCE & TECHNIQUE

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PHOTOGRAPHY IN HIGHWAY RESEARCH

Allie C. Peed, Jr.*

ABSTRACT

Many applications of photography contribute to the advancement of highway technology. Conventional applications such as aerial photography, photogrammetry, and map and plan reproduction make up the bulk of photographic use in highway engineering work. In highway research, however, unique photographic techniques make possible the advancement of studies that are well documented, clearly illustrated, and backed with permanent photographic records which can be easily interpreted. These records are often made in locations or at time intervals which are unavailable except through photography.

THE FEDERAL GOVERNMENT and many of the State governments have established research divisions within their highway departments in an effort to apply scientific methods to the problems of the planning and development of modern highways and the study of materials and procedures employed in this field of work. Photography is one tool used in the study of such problems. It is the purpose of this paper to describe some of the photographic techniques and innovations that find practical application in highway research, and particularly those that are unique and not generally known.

Just prior to the last war an ingenious method was developed in Czechoslovia for producing minute glass spheres by grinding crushed glass in ball mills and subsequent fire polishing. Such glass spheres later were utilized in this country as the reflector components in highway paints and signs. This application stimulated a great deal of research activity in optics, glasses, plastics, and related marking materials. When the Czechoslovakian manufacturing methods became available in this country, several manufacturers began the production of "reflectorized" coating materials having special reflection characteristics. As a result highway officials were faced with the problem of analyzing and appraising the properties of individual commercial products.

The glass beads measure on the average about 0.12mm in diameter. Consequently, the study of their properties has required the use of the microscope. Figure 1 is a typical example of the many photomicrographs made of the several forms of glass bead reflectorization. As the reasons for the differing properties of these materials were determined, it became evident that basic principles of spherical lens optics were not only applicable but that the function of a single glass sphere, as a lens system in itself, had to be analyzed geometrically before the overall properties could be interpreted. Thus, a single glass sphere became the object of considerable study. Figure 2 is one of a series of photographs of a single glass sphere with a sharply defined, well collimated beam of light incident from the left. Smoke box techniques were used to make the light rays visible in the photograph. The distance from the rear surface of the sphere to the focal point could be measured directly on the photograph. A series of these photographs made of beads having various refractive indices

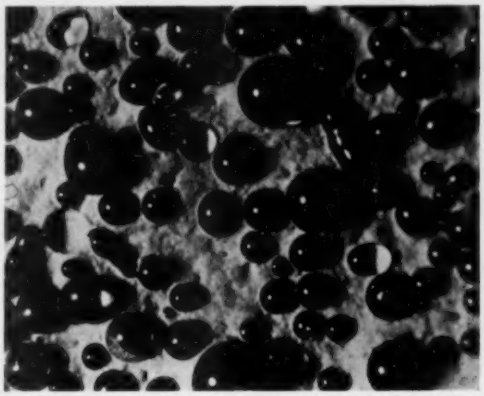

Fig. 1. Photomicrograph at approximately 50× enlargement showing reflectorizing glass beads embedded in the paint of a highway center-line. Official photograph Ky. Dept. of Highways.

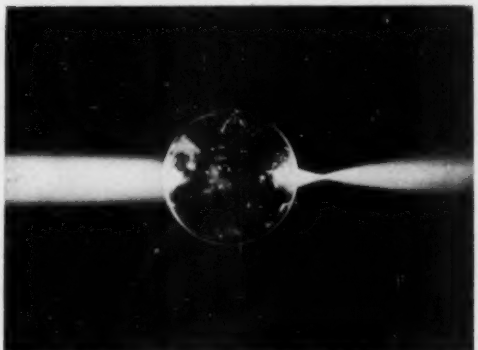

Fig. 2. Smoke box demonstration of the optical function of a single glass bead used for light-reflecting highway signs and markers. Official photograph Ky. Dept. of Highways.

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* Highway Materials Research Laboratory, Kentucky Department of Highways, Lexington 29, Kentucky. Presented at the PSA National Convention, New York, N. Y., 13 August 1952 as part of the Technical Division Symposium on Photography in Engineering and Science. Received 18 August 1952.

and other physical properties served as the starting point for a mathematical analysis of the theory of the optical performance of spherical lenses as applied to retrodirective reflectors.

When beads of this type are used for "reflectorizing" centerlines or surfaces subjected to traffic, many are dislodged and lost unless the beads are properly imbedded in the paint binder. Rhodes and Pocock, in the course of a study of influence of interfacial tensions and wetting characteristics on retention mechanisms, designed a stereophotomacrographic camera with which they were able to photograph beaded surfaces at considerable magnification. Figure 3 shows a camera used for this purpose. Stereoscopic study of the magnified photographs was of considerable aid in determining bead retention mechanisms, depth of bedding, and other important surface characteristics. This type of "reflectorization" is essentially the same as that used with beaded motion picture screens except that the cone of reflection for the latter is purposely made much wider to accommodate the closer viewing conditions. As a result of these studies, in which photography played a major role, specifications and testing procedures have been formulated that ensure proper selection of beaded marking materials.

It was feared that because of the difficulties which had been encountered in the projection of polarized stereo images on beaded-type projection screens a similar diminution of the effectiveness of beaded-type highway sign surfaces might be experienced if polarized lights and polarizing windshields came into use. In the report of the study of this problem color photographs carefully made under actual driving conditions were most effective in demonstrating the use of such a crossed-polarizer for reducing the glare of approaching headlights.

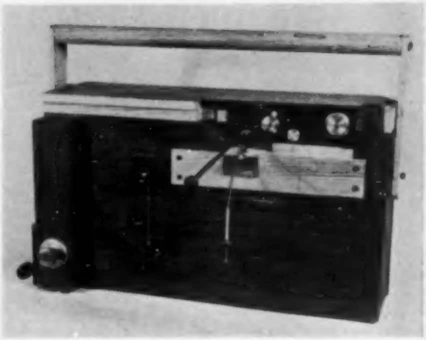

Fig. 3. Stereophotomacrographic apparatus. A 35 mm. camera with lens extension tube is mounted in the housing with integral batteries and light source. Two successive exposures from two positions yield stereographic pairs of prints or transparencies. Photograph by courtesy of Michigan Department of Highways.

Use of Photomicrographs

In the studies just mentioned, objects near the limit of resolution of the unaided eye were evaluated and therefore optical and photographic magnification in the order of 50 to 100 diameters was required to facilitate visual examination. There are instances in which even smaller objects must be examined, necessitating even higher magnifications. Since most roads are built with large quantities of mineral aggregate, an understanding of the properties of such material is mandatory. A study was made of stone samples taken from the vertical face of four limestone quarries at one-foot vertical intervals. As a part of this work, thin sections were ground from each sample in two orientations and photomicrographs made by transmitted light. Altogether 1200 photographs were made and filed according to the position of the stone samples in the quarries. Thus the geologic and physical variations within the quarry can be ascertained readily from the photographs.

In a similar project the photomicrographs were made in color since the examinations were made with the petrographic microscope and the colors obtained upon use of phase contrast techniques were most descriptive of the sandstone materials. As an adjunct to this study it was desired to determine what amount of the sandstone was granular material and what portion was matrix or cementing material. Since the granular material was generally more transparent than the cementing material, it was possible to estimate the relative proportions of matrix material from photographs made on high contrast film of the thin sections. Exposure and processing of the film could be adjusted to yield images in which the granules were opaque and the cementing materials essentially clear on the negative. An integrating densitometer was used to measure the total amount of light transmitted by such negatives and these measurements were compared with the transmission of an unexposed and a fully exposed sheet of the same type of film processed identically. The amounts of granular and cementing material then were calculated from these transmission values. This method was checked against one involving laborious planimeter measurements of a camera lucida image and was found to

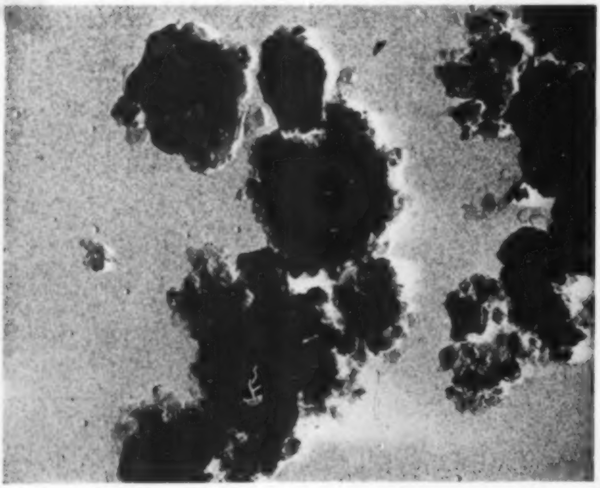

Fig. 4. Electron micrograph at a magnification of 20,000 diameters showing clay particles smaller than one micron in size. Shadow-cast technique makes vertical as well as planar dimension measurements possible. Official photograph Ky. Dept. of Highways.

be quite accurate. By this method it was possible also to correlate percentages of cementing material with actual strength tests.

In highway construction work, an understanding of the supporting capacity of soils and their other engineering properties is an obvious necessity in the evaluation of foundation conditions and surface requirements. In an effort to examine all of the ingredients of the soil, electron photomicrographs were made of the smallest particles to supplement photomicrographs of the larger particles. Figure 4 is an electron micrograph of 21,000 diameters magnification which made possible the examination of form and structure of particles considerably smaller than one micron. This particular electron micrograph was made with the shadow-cast technique which produces shadows that are five times the vertical height of the object. Thus planar dimensions are measurable directly whereas vertical or thickness dimensions can be determined indirectly. Such data are important to an understanding of the engineering properties of any soil.

Photographic techniques are not limited by any means to the representation of the physical appearance of the specimen. They may be used to record other properties which indirectly describe the nature of the material under study. In the above mentioned study of soils, a knowledge of the crystallographic structure of the soil particles is of great importance as well as their exact chemical composition. Physical and chemical analyses are expensive and time consuming but photography can be used to obtain the required information more readily if it is combined with x-ray diffraction methods. Figure 5 shows three typical x-ray diffraction patterns obtained from samples of soil constituents.

Another photographic technique is used in the interpretation of x-ray diffraction patterns. As the principal interference lines are measured and identified, their photographic opacity is measured on a transmission-type densitometer; and the "weight" of each line with respect to the others on the same pattern is taken as a relative measure of the quantity of that particular material in the specimen. The same equipment has been used to make microradiographs of the thin sections of minerals mentioned previously. Photographic enlargements of the resulting diffraction patterns showed much of interest concerning the internal structure of the sections.

Fig. 5. Three typical x-ray diffraction patterns of soil constituents. The distance of the lines from the center point serves to identify crystallographic properties of the sample while the weight of each line is a quantitative measure of the amount of substances present in the sample. Official photograph Ky. Dept. of Highways.

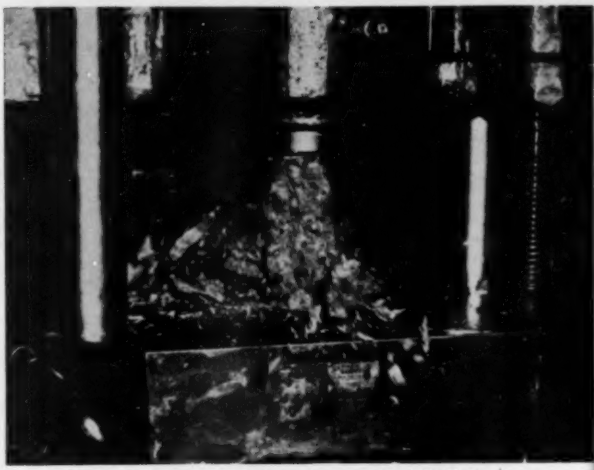

Fig. 6. Photograph made with a regular foil-filled flash bulb triggered electronically by the sound of the breaking of a concrete test cylinder. Official photograph Ky. Dept. of Highways.

Motion Picture Applications

Use has been made of ultra high-speed motion picture techniques in the highway field. Motion pictures at normal speed have been of some value in the Marshall Stability Test which is used widely to determine the worth of asphaltic pavement mixes. This method consists of rapidly loading a four-inch cylinder of the compacted test mix until it fails or loses its ability to support further load. While the load is being applied stress and strain measurements are made simultaneously to determine the load-bearing properties of the mix. Since the loading is very rapid (most tests lasting only three to six seconds from start to failure) manual recording of the stress-strain dials is impossible. With a motion picture camera, the readings of the two dials can be recorded accurately and at the same time changes in the specimen recorded as it approaches ultimate failure.

Stop-motion Flash Techniques

Electronic-flash technique is used for recording failures of concrete test cylinders in compressive tests, or concrete beams in flexural tests. In such tests the failure of the rigid concrete specimen is usually explosive in character, and the nature of the failure of engineering interest. Although high-speed motion pictures admirably record such events, a single photograph properly spaced after the failure starts, serves the purpose just as well. Electronic-flash makes it possible to "freeze" the crack structure as well as the displaced fragments just as they appear at any selected time after the instant of failure. This type of photograph has been made using a microphone to detect the sound of the failure. Amplified electronically, the sound is used to close a relay which

Fig. 7. Condition photograph of transverse traffic paint stripes after one year of in-service testing on a highway. Official photograph Ky. Dept. of Highways.

triggers the camera and flash. The variable delay factor can be introduced electronically in the amplifier circuit, but it has been found easier to adjust the distance between the microphone and the specimen and use the transit time of the sound waves as the delay factor (each foot of removal from the specimen location introducing approximately 1/1000th second additional delay). Thus a contact microphone affixed to the cylinder gives a photograph essentially at the instant of failure, while a microphone five feet from the cylinder gives a picture approximately five milliseconds after the failure. Regular foil-filled flashlamps can also be used and their delay-to-peak used as the lag factor. Figure 6 is a photograph of this type made with a regular flashlamp. It will be noted that the particles flying in mid-air are not completely stopped by this type of light.

Field Photography

The use of the camera in field work is considerably older than the highway research laboratory photography, consequently a greater amount of it has been done. Bridges, dams, buildings, and roads are all permanent fixtures of the place in which they are constructed and about the only manner in which they can be described and studied elsewhere is through some sort of graphic representation. Drawings, maps, plans, and sketches are used for such purposes in the technical fields, but these are not readily understood by non-technical persons. Photographs of the projects can be descriptive to the layman or technician in some other field who is not familiar with the symbols and convention of the engineers that are more directly concerned with this work.

In this type of photography, as in laboratory work, the photographic record not only serves as the eyes of the engineer, but it also serves as the memory. Since most engineering projects are designed to withstand many years of use, it is important to document the manner in which they age. Much can be learned from past construction that is of benefit in current work. In the highway field it takes fifteen or perhaps twenty years to establish the worth of new materials and construction methods incorporated in full-scale field performance tests. Even then a comparison must be made with normal types of construction placed at the same time. Photography can document the slow failure of a surface or structure over several years time and provide a comparison with another section of different construction finished at the same time but many miles from the first.

Progressive failure of materials over shorter periods of time are of importance also. For example: traffic center-line paints are purchased by many highway departments on the basis of trial service tests. Competitive samples are placed as transversed stripes on the road at one location. The performance can best be shown by a series of documentary photographs, preferably in color, made at regular intervals throughout the duration of the test. Figure 7 shows such a series of stripes after one year of service on the road.

Most field testing and inspection of highway materials and construction can be well supplemented and documented by photographs of culverts, bridges, surfaces, shoulders, drainage ditches, and traffic facilities made by an inspector. Photographs of this type serve also as invaluable aids in tracing the history of a failure provided that photographs were made at regular intervals during the life of the unit.

Highway Traffic Studies

In pattern studies of vehicular traffic and driver behavior, use is made also of photographic techniques. In a study on the influences of several different types of warning signs and pavement stripings on vehicular guidance at narrow bridges, members of the Indiana Joint Highway Research Project used a motion picture camera with electric drive mounted on top of a roadside sign or an overhead bridge member. An unusual feature of this work was the use of a temporary grid laid out on the pavement which was photographed from the camera position and then removed so that the drivers would not be distracted by an unusual pattern on the

Fig. 8. Enlargement of a single frame from 35mm sequence photographs used in the evaluation of driver behavior. Note the image of the timer and counter in the lower right hand corner. Sequence-views make it possible to determine driver responses at arterial intersections. Photograph by courtesy of the University of California Institute of Transportation and Traffic Engineering.

pavement. When the data were evaluated in the laboratory, two projectors were used—one to project a still frame of the grid, the other the motion pictures of the cars. These images were superimposed on the screen. As a result the cars appeared to move across the target grid and lateral placement data were easily transcribed.

In a somewhat similar study conducted at the Institute of Transportation and Traffic Engineering at the University of California, Los Angeles, Forbes and Reiss adapted a 35mm motion picture camera to make aerial photographs in sequence from a light aircraft. The camera was arranged to yield single exposures at fixed intervals controlled by an electric intervalometer at a higher than normal shutter speed (1/250th second) and at the same time photograph through the back of the film a counter and timer in a corner of each frame. Figure 8 is a single frame from such a sequence. This apparatus was found useful in the study of driver behavior on freeways, at intersections, and traffic interchanges. Similar studies made at George Washington University used regular, large film, aerial still photographs in addition to 16mm and 35mm still and motion pictures in both color and monochrome.

Conventional aerial photography and photogrammetric techniques are finding widespread use in preliminary highway location work and in outlining of drainage areas. The low altitude strip-mapping technique has been used to make performance surveys on pavements. A whole new field of soil identification and mapping has been developed within the past few years using aerial photographs. These new techniques make possible the tentative interpretation and mapping of soil-types over large areas. As a result, field work is well defined before it is started and is greatly facilitated by the fact that only a few samples need be taken in each area to corroborate or disprove the clues offered by the aerial photographs.

In a cooperative project conducted by the Highway Research Board, The Asphalt Institute, and the Bureau of Public Roads on the structural design of nonrigid pavements, photography was used as a recording method in the field. Photography contributed to a change in the test procedure which speeded up the testing from one test per day to an average of four tests per day. In this work, static bearing tests were made involving load-deformation data taken simultaneously from the surface, base, and sub-grade of an asphalt pavement with a variety of sizes of bearing plates. Under the revised accelerated test procedure, tedious reading of the three deflection dials and the load dial was turned over to a Robot camera. This, of course, greatly expedited the work; and, as each increment of load was added, it was only necessary to press the shutter release of the camera and to proceed to the next application of load.

PHOTOGRAPHY HELPS DEVELOP ROCKETS AND GUIDED MISSILES

R. W. Herman*

ABSTRACT

Photography plays an important role in the testing of rockets and guided missiles. The theory and history behind various data-gathering methods are described. The principal ballistic parameters are classified and basic techniques for measuring them are described, together with some of the problems involved in applying these techniques. This study forms the basis for a discussion of new and future developments in the field of measurement photography.

PHOTOGRAPHY PLAYS a vital role in the development of the new science of rocketry. In order to realize the full significance of this statement, it is necessary first to gain an insight into some of the problems facing the scientists responsible for the development of rockets and guided missiles. Some of these problems are encountered with other ballistics such as artillery shells or in aerodynamic fields. However, many problems are unique to rocketry as, for example, those of finding smoothly burning propellants or evolving aerodynamic designs stable under conditions of rapidly varying weight distribution.

The testing of new designs also has unique features since only meager data can be gathered from wind tunnel or static tests concerning many design factors. Testing must, therefore, be done under dynamic conditions in which the component is allowed to function under normal environmental conditions. The recording of the necessary test data becomes a difficult task under these conditions since no direct mechanical contact with the test object is possible when it is in free flight.

Visual observations of the various phenomena are, of course, entirely inadequate due to the high speed of rocket flights. Although many methods have been devised for gathering quantitative data concerning the various test objectives, the major portion of these systems use photographic materials for recording purposes. Millions of feet of photographic film and paper are used annually to record electronic measurements, such as

* Metric Photographic Branch, Instrument Operations Division, Test Department, U. S. Naval Ordnance Test Station, China Lake, California. Presented at the PSA National Convention, New York, N. Y., 13 August 1952, as part of the Technical Division Symposium on Photography in Engineering and Science. Received 11 August 1952.

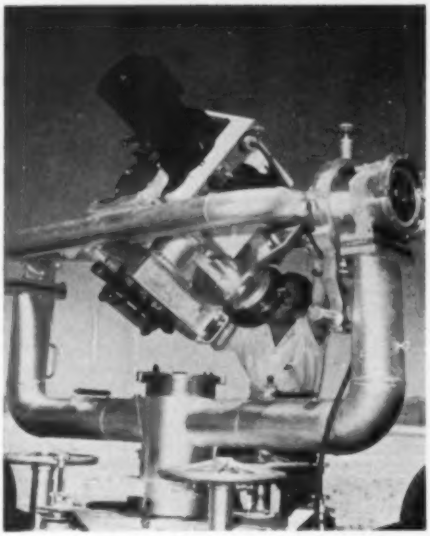

Fig. 1. Scale settings of the Bowen CZR-1 Acceleration Camera, derived mathematically from predicted trajectories, are set into the instrument. When the rocket is fired, it passes through the camera field of view, and the pictures can be related to these angular settings. This camera uses film which is 5-½ inches wide and takes pictures at the rate of 30, 60, 90 or 180 per second. Small projectors inside the lens housing print reference crosses on each frame. These fiducial marks are carefully calibrated to the orienting scales on a precision test range. Such a procedure is necessary, since the camera is usually pointed into the sky so that no "ground control" references are available in the picture. Official photograph U. S. Navy.

Doppler radar signals, pressure gage dials and magnetic pick-up signals. Most equipment consists of both electronic and photographic components and a given recording facility can only be called an "electronic" or "photographic" device from a consideration of the primary data-gathering emphasis. Some of the data requirements best determined by equipment which is primarily photographic in nature are described in this report.

Ballistic Requirements for Photographic Data

For the purposes of photographic instrumentation, rocket ballistics may be divided into three phases distinguished by different data emphasis as well as natural ballistic boundaries. The first phase covers the launching and initial acceleration period. Here the performance of the rocket motor is of primary interest. Since this performance is reflected in the acceleration characteristics of the missile, measurement of these characteristics gives important clues to what is happening in the rocket motors. Other important factors which can be determined photographically include such items as booster separation studies, "tip-off" or launching angle drop of a missile during the acceleration period, rotational velocity, yaw oscillation periods, and dispersion.

The second phase covers the flight of the rocket after the initial acceleration. In this phase, the rocket either coasts, slowly losing speed due to frictional forces, or else the velocity gained during the acceleration period is maintained by a "sustainer" motor. It is during this phase that the ballistician wishes to evaluate the aerodynamic characteristics of the design and the functioning of the guidance mechanisms. Two types of determinations form the most important photographic contributions to these investigations. The first of these is trajectory measurements involving the determination of position versus time at a predetermined sampling rate. These data furnish information concerning the guidance behavior of the missile and, by successive differentiation, velocity and drag or deceleration values. The second is attitude measurements used to determine the orientation of the missile at selected trajectory points. These orientation measures are classified according to their relationship to the line-of-flight axis of the missile. Roll or spin describes oscillation or

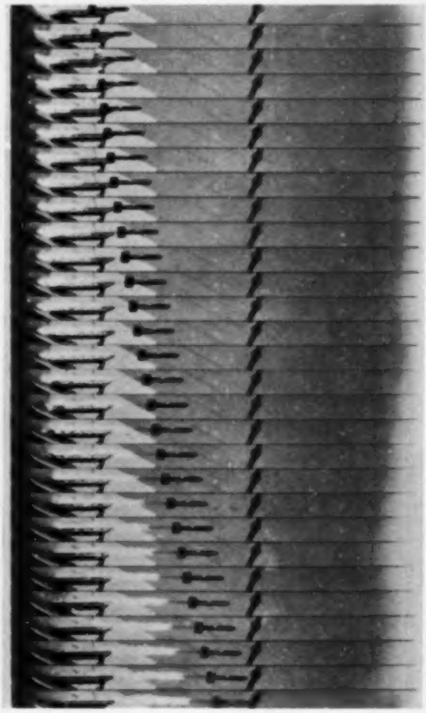

Fig. 2. The launching of a TINY TIM rocket as pictured by the Bowen Acceleration camera. The camera is oriented with the length of the frame along the trajectory, so that the ground appears at an angle along the left margin. Official photograph U. S. Navy.

rotation about this axis, while pitch and yaw describe the vertical and horizontal components of transverse oscillations of the missile about its center of gravity.

The third phase is often called "Terminal Ballistics" and concerns the various factors involved in the ending or termination of the rocket's flight. The nature of these requirements will depend upon the use for which the rocket is designed. For example: if an anti-personnel rocket were being designed, then the terminal factors desired would probably have to do with fuze functioning and fragmentation patterns. Some of the other types of data often desired in terminal ballistic studies include such determinations as target entrance angle, target penetration and explosive order.

Reflection upon these data requirements will indicate the wide variation in instrumental design factors necessary to make all these measurements. For example, the conditions encountered in the first phase are such that the missile's path may be predicted within fairly narrow limits. This factor allows the use of fixed instruments which can be oriented accurately in such a manner that the missile will pass through the field of view. But these conditions do not hold for the second phase and the instruments must therefore follow the moving target.

Fig. 4. Battery of three Mitchell High-speed 35mm motion picture cameras set up to record the launching of a LARK missile. Such detailed studies are valuable for determining the functioning of various components during this critical period of the flight. Official photograph U. S. Navy.

Photographic Solutions to the Ballistic Requirements

Photographic methods for gathering the data indicated above are generally classified according to their primary design functions, although most cameras are used for a variety of purposes and often several types of data can be had from the same record.

Fig. 3. The Askania cinetheodolite is used on guided missile tests to provide triangulation data for surveying the missile's position in space, usually at the rate of four times per second. The camera is tracked or pointed at the rocket by sighting through the telescope and moving the instruments by means of a handlebar. A picture of the missile is recorded simultaneously with angular scale readings which are imprinted by means of Edgerton flash lamps. The scale images are compared to an optical scale divider and transferred to the film through complex optical trains. Official photograph U. S. Navy.

The camera most generally associated with initial phase studies is the Bowen Acceleration camera. This camera (Figure 1) was originally developed by Dr. Ira S. Bowen, currently director of the Mount Palomar Observatory, and has undergone several subsequent engineering revisions. The latest version is designated the CZR-1 and is used in conjunction with a newly developed precision three-axis orienting mount.

As its name suggests, this camera was primarily developed for acceleration measurements. There is no photographic way to determine acceleration directly. Therefore, position in space versus time is the data actually determined, and the accelerations are mathematically derived by successive differentiations. Since errors are compounded in this process, the original positional measurements must be extremely accurate if meaningful results are to be had.

The cameras are operated as "fixed" cameras—that is, no tracking is attempted. They are oriented in such a manner that the rocket will pass along the camera's field of view. The camera is known as a "ribbon-frame" camera because of the shape of the pictures it takes (see Figure 2). Since the primary measurement interest is along the rocket trajectory, the frame has a long, narrow configuration, measuring five inches long by one inch or less high depending upon the frame rate chosen. The camera can be run at thirty, sixty, ninety or 180 frames per second.

Since measurements are critically important only along the length of the frame, an important degree of freedom is released for utilization in the mechanical design of the camera, and the film is therefore kept in continuous motion throughout the exposure. The blurring which results is in a direction perpendicular to the image motion and is roughly comparable to blur due to the velocity of the rocket. The exposure time is variable between 1/10,000 and 1/50,000 second.

The orientation of the camera is accomplished by means of a mount which allows motion about three axes; azimuth and elevation, which are mutually perpendicular with the optic axis of the camera, and roll, which is parallel to the optic axis. These motions are measured by very accurate scales. Small fiducial marks are projected on the film and these are calibrated to the scales on a precision test range. Thus, by measuring the position of a rocket image relative to the fiducial marks on the film and knowing the camera position and orientation angles, it is possible to locate a line in space along which the rocket appeared. The only other factor necessary for complete location of the missile in space is the determination of the position along this line. This is usually accomplished by means of a "deflection plane" which is measured by motion picture cameras located either behind the launcher or under the flight line.

Time is the only common denominator among all the various types of measurements made. Determinations are therefore usually made against time and can be subsequently related to one another through this common time base. Therefore, great emphasis is placed on range timing systems and the introduction of relative time into each instrument. All time is measured relative to an arbitrary "zero" time which generally coincides with the actuation of the rocket firing circuit.

Fig. 5. The M-45 Tracking camera is shown in action tracking a missile. The mount is electrically driven, controlled by the handlebars in the operator's hands. The camera mounted to the left of the operator is a Mitchell 35mm camera with special provisions for the introduction of timing. The lens used here is a 48 inch focal length f/8 astronomical doublet of exceptional quality. On the operator's right side is mounted a half-scale version of this same lens, with provision for either a 16mm Mitchell camera for documentary movies or a Fastax 16mm camera for super slow motion studies. The lenses are mounted firmly to the side plates and the cameras are mounted on precision ways for focussing motion. Communication is by two-way radio. Timing pulses are also received by means of radio. A large generator is carried on the towing truck to furnish power for the mount drive, cameras and radios. Official photograph U. S. Navy.

Timing in the CZR-1 camera is introduced two ways. The first system utilizes the fact that the film in this camera is in continuous motion. A projection system images the light from a neon lamp on the edge of the film. This lamp is triggered by the timing system at the rate of 200 cycles per second before zero time, and 1000 cycles per second at and after zero time. Thus, a series of little marks appear along the edge of the film which define time before and after zero time. The second system utilizes an electronic binary counter which operates a group of neon lights in such a manner that a code is photographed in each frame which indicates the time lapsed from zero time.

Several of these cameras are normally used on a test. They are so oriented that each camera covers a portion of the trajectory, but slightly overlaps the coverage of the previous camera so that a continuous record can be pieced together. It sometimes happens that dispersion is so great (that is, the path of the rocket is so unpredictable) that several cameras must be used to cover the same trajectory segment. The cameras are then oriented in such a manner that the fields lie one above the other so that a greater portion of the sky is covered. This assures that the rocket will go through the field of one of the cameras.

Several other types of cameras are also used in the first phase to study various factors. Motion picture cameras are sometimes placed directly beneath the flight line to record yaw oscillations. High speed cameras, such as the Fastax, are used to study highly transient phenomena such as booster separations. Most determinations, however, are obtained from the Bowen camera records.

Trajectory measurements are usually made by means of cinetheodolites (Figure 3). These are, essentially, surveying instruments which record all pertinent data automatically on photographic film. The operator follows the missile in a telescope attached to the cinetheodolite. Circular scales attached to the theodolite axes are photographed at accurately timed intervals through the use of Edgerton flash lamps. At the same time a photograph is taken of the missile so that errors in tracking can be measured and the scale readings corrected accordingly. Data from two or more (usually three) cameras located on first-order surveyed base lines several miles long are triangulated to determine a most probable position of the missile. The triangulations which are made during an average two-minute flight would take a good survey team a month to do with the same degree of accuracy, were such a procedure possible.

The problems involved in such an instrument program as this are enormous. No really outstanding cinetheodolites have yet been developed for rocketry. The most successful instrument so far has been the German Askania cinetheodolite which was originally developed for anti-aircraft gunnery practice. A number of these instruments were "liberated" at the close of the last war and have been extensively modified to adapt them to the stringent requirements of missile testing.

Timing in these cameras is accomplished by precision control of the time at which recordings are made. Pulses from a central control are sent out electronically to all the cameras in the network at precisely determined intervals, usually two or four times per second.

Fig. 6. Documentation of a guided missile launching is accomplished by this battery of special cameras. Sequencing devices automatically trip the shutters to give pictures of the missile at different times as it is coming off the launcher. By using large lenses and fast shutter speeds, spectacular color illustrations of launchings are obtained. Official photograph U. S. Navy.

These pulses trigger flash lamps which produce the angular recordings. The main shutters are actuated in such a manner that the picture of the rocket is simultaneously recorded with the scales. Thus, the records are made at the same known time in all the cameras operating on the range, a factor which facilitates the data reduction process.

There are two basic approaches to the problem of measuring attitude. The most accurate method is to place a camera inside the missile and photograph ground targets. This procedure is essentially the photogrammetric process in reverse. Another variation of this method is the "solar yaw camera" or "Widget," which traces the excursions of a pinhole image of the sun as the rocket maneuvers. Usually, however, no space can be spared inside the missile and all measurements must be taken from the ground. To do this, photographs are taken of the missile from at least two positions with motion picture cameras equipped with very long focal length lenses so that the pictures will be large and easily measured. The apparent angle of the missile with respect to each camera reference system is measured and these data are then mathematically converted to attitude angles with respect to the range coordinate system.

Focal lengths as long as one hundred feet have been seriously contemplated for the lenses used with attitude cameras. Forty-foot focal length cameras are already a reality. The mechanical problems involved in tracking the missiles with such cumbersome instruments necessitate the creation of monstrous tracking mounts with powerful drive systems.

Much of the more recent developmental work on attitude cameras has concentrated on lenses of more conservative focal lengths with exceptional image quality. The M-45 tracking camera, for example, is a versatile instrument. Popularly known as the "Gooney Bird," the latest version of this instrument utilizes an M-45 50-calibre machine gun mount for the tracking mechanism. This is mounted on a trailer with stabilizing jacks and leveling provisions. A refractor of 48-inch focal length is mounted on one side of the operator and a half-scale version of this same lens is mounted on the other side. Pictures for attitude purposes are recorded by means of a Mitchell 35mm chronograph camera. A 16mm Mitchell camera may be used for documentary motion pictures or a Fastax camera for super slow motion studies. Each Gooney Bird is powered by its own generator system, which is mounted on the towing truck.

The problems encountered in terminal ballistics are so many and so varied that only a few examples of some of the optical methods will be mentioned. In many applications, Bowen cameras are used to give a record of such things as target entrance velocity and detonation pictures. Sometimes high speed studies are desired to determine such things as entrance angle or fragmentation studies. These cameras are set off to the side of the target in a fairly straightforward manner.

Some of the more unusual problems involve such things as detailed high-speed studies of the detonation of a rocket head. Since the explosion creates an enormous amount of self-luminosity, the lens must be slowed down to its smallest aperture to enable detail in the explosion to be recorded. When this is done, however, no part of the rocket which is not self-luminous will record, and important correlative detail will be lost. One solution to this problem is to use a screen with a coating of material which reflects light directly back on the course from which it comes. This screen is placed on the far side of the target from the camera and a large searchlight beamed on it from directly behind the camera. The light coming from the screen sharply silhouettes the non-luminous portions of the rocket, making them visible and easily distinguished from the explosion details.

Photography's part in helping to develop rockets and guided missiles is not limited to the making of scientific measurements. The more conventional types of photography play an important role in documentation of the research and testing programs. Thousands of still photographs and more thousands of motion picture films testify to the truth of the old adage that "one picture is worth 10,000 words."

Rocketry plays a dominant role in National defense plans. The security of our country depends upon the success with which our scientists overcome the problems they face in the development of new defense weapons. Rocketry also holds the key which will someday open the vast new frontiers of the universe to man's exploration. It has already helped him in his quest for knowledge beyond the earth by carrying his instruments outside the atmosphere to gather data. Here again, photography plays an important part as a recording medium.

PHOTOGRAPHY IN THE TEXTILE INDUSTRY

Melvin Siegel*

ABSTRACT

High-speed still and motion pictures, and time-lapse and other types of photography, have aided in the design of textile machinery, permitted the observation and recording of various phenomena otherwise impossible to study, and facilitated recording of all types of data. Research studies of various types have been aided materially by electron micrographs, X-ray diffraction, and fluorescence, ultraviolet, and infrared photographs. Examples of such applications are discussed and illustrated.

INDIVIDUAL FIRMS within the textile industry have independently employed photography as a tool and are probably exploiting its use more than other industries, judging by the recent literature.[23, 51, 52]

Microfilms, photostats, and photographs for patent purposes are applications in which photography is used routinely, as are photographs for advertising and for use in house organs.

Some mills[17] use photographs showing wear of component parts of machines as a guide to purchasing. They also make photographs of machines with various size change gears and pulleys. These are placed in the hands of production supervisors and the speed of any of the production machinery easily determined by comparison with the standard photographs, where the speed is noted. In the installation and erection of machinery, photographs are used to a considerable extent to assist in their rapid assembly.

Combination photographs (superimposed titles or numbers on the print) for designating the individual parts that go to make up an assembly are used[13] by some machinery manufacturers. These are employed in connection with installation and operating instructions, as well as to serve partly as a parts list for the ordering of replacements.

The textile fibers that comprise a yarn are very fine and delicate. Their very small diameter is usually expressed in microns. The length of these fibers is an important consideration in the setting of yarn manufacturing machinery as well as deciding what type and size yarn may best be made. A random distribution of separate fibers from a single lot, known as a sliver diagram, permits the amount of various fiber lengths in that lot to be determined. Photography offers the only means of keeping these very delicate sliver diagrams in permanent record form.

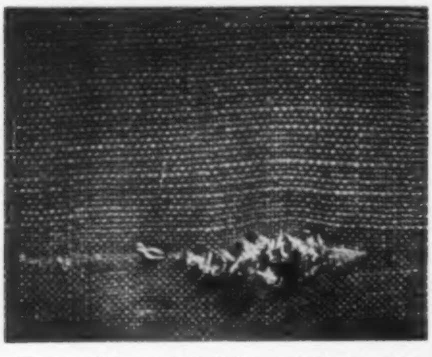

Fig. 1. Photograph of cloth swatch showing defect in hospital sheeting. Similar photographs are useful for studying the evenness of yarn, fullness of fabric, and as evidence in support of claims. Photograph by courtesy of U. S. Department of Commerce, National Bureau of Standards.

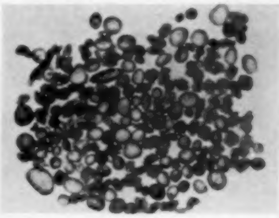

Fig. 2. Photomicrograph of a cross-section of a mixed yarn useful for identification of the various fibers as well as for quantitative analysis of the yarn. Photomicrograph by courtesy of U. S. Department of Agriculture, Southern Regional Research Laboratory.

The study of mildew on fabrics has been made by the National Bureau of Standards[1] and others. The effects of various mildew-inhibiting chemicals, and the extent of mildew growth on test specimens can be permanently recorded and measured through the use of photography.

Photographs of cloth swatches[10] graphically show evenness of yarn, fullness of fabric, fabric defects, etc. The National Bureau of Standards (Figure 1) have done work along this line in evaluating defects in hospital sheeting. Many mills standardize the nomenclature of these defects by having their fabric defect photographs on display in their various production departments so that all personnel may realize the nature of the defects and help eliminate them. Correct identification of fabric defects has become so important in settling claims, that Goldberg has compiled a series of such photographs in book form.[16]

The National Bureau of Standards have employed photography to show the extent of rug wear after subjecting samples to a known amount of abrasion.

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*Jean Ribbon Mills, Inc., Paterson, N. J. Presented at the PSA National Convention, New York, N. Y., 13 August 1952, as part of the Technical Division Symposium on Photography in Engineering and Science. Received 26 August 1952.

Lantern slides and motion pictures are also used to show how to operate and maintain various machines, with animation techniques when necessary. Motion pictures are used as a sales aid[25] for export areas, so customers can view equipment in mill action under actual use, as well as to see general performance. Time and motion studies in the textile industry also make use of standard techniques employing motion picture photography.

Photomicrography

Photomicrography is employed extensively in the textile industry, from the metals and alloys used in the manufacture of machinery to the yarn in the finished fabric. All textile fibers appear different microscopically, and there are several complete photographic references available in published form[40, 42, 54, 56] to be used as an aid to identification. Photomicrographs of yarn are used for the qualitative and quantitative analysis of mixed yarn.[8] The amount of each fiber in a blended yarn (Figure 2) can be verified by photomicrography[17] in accordance with the Wool Labeling Act. This is done to determine whether the actual blend is in accordance with the requirement as there is usually a greater loss of one of the types of fibers in the manufacture of blend than in another.

Swelling studies of various fibers and yarns when wet have been the subject of investigation.[32] When wet, cotton has shown an increase in area between 21% and 34% greater than the dry area. This information is basic and important for fabrics used for fire hose, military fabrics, and tarpaulins, which become more water resistant as they are wet due to this swelling and so prevent water from passing through. These data are also useful for studying fibers used for fillers for plastics, for warp yarns in carpets, and for industrial fabrics of all kinds where changes in dimension due to moisture are important in processing and in use. The increase in the area is measured from these photomicrographs, and the information gained assists in the designing of such fabrics.

Coating studies of various types have been aided by photomicrographs. In the study of fibers to which

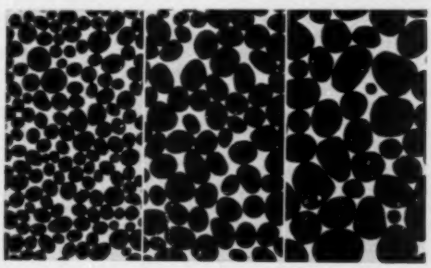

Fig. 3. Photographs of cross-sections of fine, medium, and coarse wool fibers from USDA film strip. This film strip, when projected at a given enlargement and compared with actual wool fibers in a microprojector at 500×, measures the mean fiber diameter and standard deviation of wool fiber samples. Photograph by courtesy of U. S. Department of Agriculture, Wool Standards Laboratory.

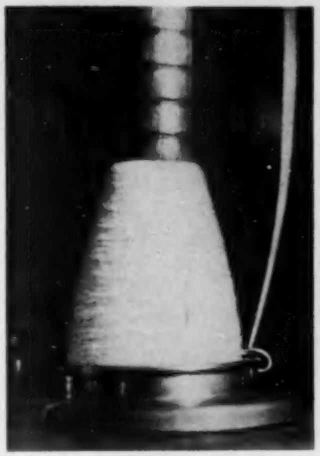

Fig. 4. High-speed photograph of a ring spinning frame traveler rotating at 8880rpm taken at a speed of 1/75,000 second. Engineering studies of such photographs aid in design and improvement of these travelers. Photograph by courtesy of Victor Ring Traveler Co.

various amounts of a latex dip, necessary for obtaining satisfactory bonding to rubber as in a tire carcass, have been applied.[24] Through the examination of fiber cross-section photomicrographs,[9] the extent of the dip penetration can be followed as a function of the process variables.

Properties of fabrics may be considerably altered by impregnation with various chemical compounds. Crease resistance in fabrics is obtained by impregnating the cloth with any one of several resins.[6] Starch sizing on a cotton yarn, as well as rot proofing, mildew proofing, fire proofing, and moisture proofing, are but a few in which the degree of impregnation in regard to depth and uniformity may be studied by means of photomicrographs.[3]

As a guide to the selection of fibers which are more abrasion resistant, and hence will wear longer in a fabric, duPont has dyed yarns from worn fabrics with Congo Red. This dye has the property of dyeing mechanically damaged fibers a deeper color than undamaged fibers.[5, 6] Photomicrographs in color of the fibers of the abraded yarn, readily show the severely damaged fibers.

Promotion of Standards

Photography has been used for the maintenance of standards in the textile industry. The Agricultural Marketing Administration of the United States Department of Agriculture and the American Society for Testing Materials have developed a series of photographic yarn standards[27, 33] to show the uniformity of cotton yarns. These are known as the Cotton Yarn Appearance Standards and consist of five boards with four photographs on each. Each board is for a different group of yarn sizes, with four grades on each board.

Various fiber dimensions[28] of cotton yarns are important for the yarn spinner or manufacturer in helping him decide the type and size of yarn he should make. The American Society for Testing Materials suggests the use of photomicrographs from random cross-sections at a standard magnification. Various dimensions may then

be obtained from these photomicrographs and then used for statistical analysis. Areas of the photomicrographed cross-sections may be measured with a planimeter, and the amount of mature and immature cotton determined.

The measurement of wool fiber diameters[26] have been of great concern to the wool manufacturer. Reliable, rapid methods of measurement for the grading of wool[37] have been developed for the examination of the causes of variability of wool products[10] during manufacture, for general quality control for studying wool growth and production, and for Government specifications. Thin cross-sections of fibers are prepared in a special fiber microtome[18] and are placed in a projection microscope and projected at 500×. The cross-sections are compared with photographs of cross-sections of standard samples of wool (Figure 3) of which the mean fiber diameter and its standard deviation are known.[38]

The method has been developed so that it is suitable for routine use in mills. These standards are on a 35mm film strip. The film strip projector is suitably mounted in relation to the projection microscope so that the image of the test sample and the standard are each projected side by side for easy comparison. Such a film strip has been prepared[24] and comprises 65 standard cross-sections covering 13 grades of wool with five different standard deviations of fiber diameter for each grade. By this means large numbers of fibers may be viewed and fiber contours determined very rapidly.

The use of this method for checking blends of wool for manufacturing purposes has many advantages. Fineness and uniformity are of fundamental and basic importance in determining the grade and value of wool, as well as determining the use to be made of specific lots and the most suitable blending and processing techniques. These fiber images may also be projected on photocopy paper. After processing, the photocopies may be measured and also provide a permanent record of fiber diameter and variability of the sample, as well as a guide for making up and matching previous blends for delivery and sales purposes.

High-Speed Photography

High-speed photographs, both still and motion picture, have been of considerable aid to machine design and analysis of performance. High-speed still photographs made by the use of the Stobolux and the Strobotac[14] permit the recording of machine operations at any instant of a mechanical cycle, with a flash duration of 1/30,000 second.

Several years ago, the Victor Ring Traveler Company made some photographic studies (Figure 4) to improve the design of the travelers they manufacture.[31] A traveler is used on a ring spinning frame, a machine which spins cotton yarn, and is responsible for the twist being inserted in the yarn, as well as contributing to the strength, elasticity, and other properties. The traveler may rotate as fast as 10,000 rpm, or more than a mile a minute. If these travelers were not balanced properly they would not only wear out very soon, but also produce uneven yarn. Edgerton made high-speed photographs of this apparatus in operation which aided Victor in the development of their improved travelers. The Stobolume[14], a higher intensity stroboscope, has been used for loom shuttle motion photographs and studies.[42]

High-speed motion pictures (Figure 5) have permitted an appreciation of a machine in operation at full speed with all the various forces acting which affect operation. These motion pictures permit studies of the machines to see if they are operating at peak performance and to indicate whether any changes in setting are necessary. Crompton & Knowles pioneered in the use of high-speed motion pictures as an aid to loom design and developed special apparatus (Figure 6) for that purpose.[35] They claim that their equipment has the advantage of increased definition and clarity as their individual exposures are in the order of 1/200,000 second. They use the camera[36, 39, 46] not only to record behavior of moving parts, but also to measure velocity and acceleration of parts, like the shuttle, which as freely moving bodies have no direct connection with the loom itself.

The Eastman High-Speed camera permits the taking of as many as 3000 pictures per second, and Edgerton, Germeshausen, and Grier[12] manufacture a High-Speed

Fig. 6. Crompton & Knowles (Loom Works) high-speed camera providing 1/200,000 second exposures for recording the behaviour of fast moving parts and for measuring velocity and acceleration.

Fig. 5. High-speed motion picture setup for studying bobbin transfer. Photograph by courtesy of the Draper Corporation.

Stroboscope for use with the Eastman camera to provide a flashing rate of from 10 to 6000 flashes per second when necessary.

Schwarz[43] and his associates at MIT developed the Slater Impact Tester for determining the impact strength of yarns and fabrics. In use, either a 25 or 500 pound weight is released from a magnet located above the ceiling. As it falls, it picks up the lower end of the specimen which is held in a floating jaw, and carries it to failure. An electric strain gauge supports the upper end of the sample and registers on an oscillograph the acting force. This almost instantaneous image on the oscillograph is then photographed (Figure 7) by means of a specially designed high-speed camera and the films later analyzed.

Time-Lapse Photography

Time-lapse photography has been used by several companies for various investigations. The Universal Winding Company[22] has taken pictures at given intervals over an extended period of time (Figure 8) to record the effect of tension, diameter, temperature, humidity, and time on the winding of yarns on their winding machinery, as an aid to better machine design. The alternative to these time-lapse photographs would be manual recording which would be tedious and subject to clerical errors, and in addition, it would be impossible to record all data simultaneously.

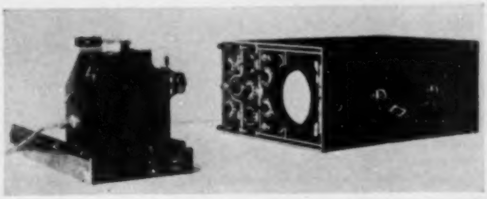

Fig. 7. Load-deformation curves for the Slater Impact Tester, registered almost instantaneously on the oscillograph screen, are recorded by a high-speed motion picture camera for study and analysis. Photograph by courtesy of Edward R. Schwarz.

The duPont Company[24] in the study of the recovery of rayon fibers from high compression have used time-lapse technique. Various fibers were crushed into pellets under pressure of about 10,000 lbs/sq in. It was found that the height recovery of these pellets was approximately logarithmic with time. To record this behavior and show an apparently linear rate of recovery, 15 minutes of recovery was shown on the screen in about a minute.

Von Bergen[35] has employed time-lapse photography in the study of shrinkage of fabrics at various humidities. Relaxation shrinkage is important in the tailoring of a garment, felting shrinkage in the washing of woolens, and the shrinkage caused by a change in relative humidity has been found to play an important part in the appearance of light weight men's suitings. This has been especially observed in suits worn in sections of the country where high humidities prevail. Photographs have shown considerable cloth movement in each direction of yarns on going from 20% to 90% relative humidity. Going from low to high humidity, the cloth stretched; going in the opposite direction, the cloth shrunk. Depending upon the type of fabric, the cloth movement varied from 2% to 4%.

Fig. 8. Time-lapse photographic records of indicator dials aid in studies of variables such as tension, diameter, humidity, temperature, time, on winding machinery. Photograph by courtesy of Universal Winding Co.

Patterns on Fabrics

A method has been developed for producing patterns on textiles by photographic means[37, 38, 39] omitting the standard equipment of very costly roller printing machines. This is a continuous process carried out in a totally enclosed chamber. A roll of cloth is passed through a sensitizing solution and dried. The fabric is then held in contact with the negative by pressure rollers. The negative is prepared in the form of an endless belt and is exposed by means of an arc light. The cloth is then developed, rinsed, and fixed (Figure 9). Techniques have been developed which permit cross-prints, mixed three-tone effects, as well as photographs combined with cloth dyed in a contrasting color.

The engraving of roller printing rolls can be accomplished photographically.[44] This permits rolls of very fine detail and gradation to be made which cannot be made with any other method. The pattern is photographed in black and white to the exact size of the roller to be used, as either a line or half-tone positive. One roller is used for each color with a separate negative for each, and usually from 5 to 12 rolls used for each pattern. Color separation is employed in only about 10% of the patterns, as it may be desired to change any color in the pattern to another without affecting the rest of the colors; and also because textile dyes when added do not react the same as does light. A sensitizing solution is applied to the roll, the positive held in contact with the roll, and exposed with an arc light. The roll is developed in water in subdued daylight. The unexposed sections of the roll are soluble in water and are dissolved. The sensitizer remaining on the roll is colorless, and it is then dyed so that the pattern is made visible. The roll is then air dried and baked, so that the sensitizer (which has a plastic base) then becomes acid resistant. The roll is retouched with asphaltum varnish

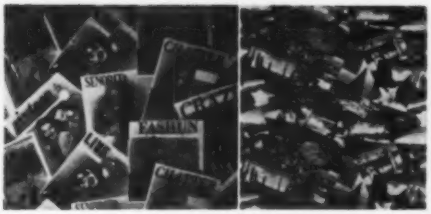

Fig. 9. Cloth patterns produced by photo-engraved printing rollers. Up to 12 rolls may be used for one pattern, each for a separate color, to obtain fine details and shadings that are impossible by other methods. Photograph by courtesy of Multitone Engraving Co.

which reinforces the acid-resistant surface. After drying, it is etched to a depth of 0.005″ to 0.006″, washed, and a trial print made.

Infrared, Ultraviolet and Fluorescence Photography

Certain dyes appear to be the same visually. In the infrared and ultraviolet range, however, they differ. During the war, certain dyes used for camouflage purposes were similar to the color of the foliage visually; but differed in the infrared and ultraviolet.[4, 7, 53] These could be easily detected when photographed from the air using infrared film. Dyes were later used which were not only similar to the color of the foliage visually, but in the infrared and ultraviolet as well. Photography has offered a simple means of testing the performance of a dye in ranges other than the visual.

Certain dyes which appeared to be the same as others visually, differed in their reflecting power for infrared. Certain uniform fabrics which were to be used for troops either in the tropics or polar regions were required to be either infrared reflecting or absorbing, as that characteristic affected the comfort of the G.I.'s wearing them. Again, through photography, there was a simple means of measuring the degree of absorption of infrared, and the coolness of a fabric actually "seen."

Areas of poor dye penetration can also be made visible and detected with infrared photography, as well as uneven dyeing exaggerated.[11] Dye streaks caused by predyed abrasion may be exaggerated by infrared, as well as undyed abrasion. A study of the interior of a dyeing machine in which the presence of steam prevented a clear view of the fabric on the reel, showed a decided improvement in the appearance of details in spite of the adverse conditions.

Employing fluorescence, active mildew on wool[41] can be distinguished by its brighter fluorescence over that of the wool itself. This can be used to detect and thus to prevent the destruction of wool while in storage. Photography has the advantage of being able to record weak fluorescent and phosphorescent effects which may be difficult to observe visually.

Millson & Royer have developed a method using fluorescent dyes for diffusion studies,[30] and for studying level dyeing.[29] Because these dyes glow in ultraviolet light, their position is revealed within each textile fiber. Slight variations in the surface structure of synthetic and natural fibers may also be detected. The penetration of dyes into textile fibers during dyeing has been studied by microscopic examination of cross-sections made from samples removed at different stages of the dyeing operation. Although this may be observed visually, all too often the light is so weak from the fluorescence that photography has to be employed so the image can be properly observed and studied.

The examination of oil-stained textiles[4] is a well established practice, and by taking advantage of the fluorescent qualities of many oils this may be adequately recorded by means of photography.

Electron Micrography and Radiography

The electron microscope permits magnifications of objects never before attained with good resolution. Photography offers the only means of recording. Various dye studies[21] have been made with the use of electron micrographs as well as information about fiber structure. See Figure 10.

Sherwood[47, 48] has shown that by using long wave length X-rays, known as soft X-rays or Grenz rays, radiographs of fabrics may be made. It is not possible to focus X-rays with a lens and thereby construct an "X-ray microscope" to reveal structures too fine to be seen by the naked eye. The only practical procedure is to radiograph the specimen upon a fine-grained film or plate and then examine the radiograph with a lens or enlarge it photographically to a degree that will enable details to be seen completely by the unaided eye. With the use of specially prepared fine-grained plates, satisfactory enlargements up to 75 diameters[15] can be made. The appearance of a radiograph of a sample of cloth (Figure 11) bears some resemblance to the visual appearance of the weave. The eye can only see surface characteristics, while the radiograph shows the effects exerted by the entire thickness of the cloth in absorbing the X-rays passing through it. A tightly twisted strand

Fig. 10. Electron micrograph of a wool fiber showing the gross scale features, produced by means of the polystyrene-silica replica technique. Illustration by courtesy of the Stamford Research Laboratories of American Cyanamid Co.

of yarn will absorb X-rays more strongly than a like strand loosely twisted. X-rays may be used to detect silks that are weighted, as lead weighted silk absorbs more of the X-rays than pure silk. Grenz ray radiography of textiles can also give information about the yarn in a fabric, and the presence and character of defects in the weave or yarn. When stereoscopic radiography[49, 10] of cloth is used, complex weaves can be readily analyzed, since it provides a method whereby the weave, suitably enlarged can be visualized in its correct spatial relationship.

Hughes[20] suggests a technique for the examination of cord fabrics in pneumatic tires by radiography. It is a non-destructive method for obtaining useful information about the internal structure.

X-ray diffraction photographs of textile fibers (Figure 12) permit the degree of orientation, both of the molecules and the axis of the fiber to be measured. The method tells the type of crystalline structure, the crystallographic spacing, the spacing of repeat units in the molecule, and the spacing between chains. These molecular properties affect certain physical properties of the fiber such as strength, elongation, elasticity, dye affinity, etc. It is probable that in the future, fibers will be built

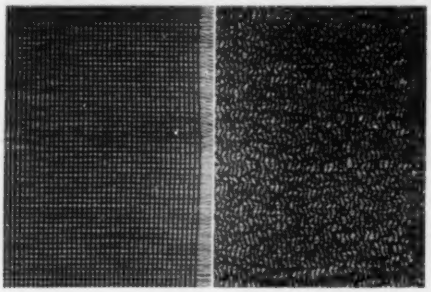

Fig. 11. Radiographs of an acetate crepe fabric before and after creping. Tightly twisted strands of yarn absorb X-rays more strongly than loosely twisted strands of the same material. Illustration by courtesy of the Kodak Research Laboratories.

to order with certain characteristic properties, and X-ray diffraction studies help considerably in analyzing these.[2] Photography offers the only means of revealing and and recording these spectra.

In this brief resume, an attempt has been made to review some of the more outstanding applications in which the textile industry is making use of photography. This is by no means complete, and is offered as a guide to suggest what can be done using this versatile tool.

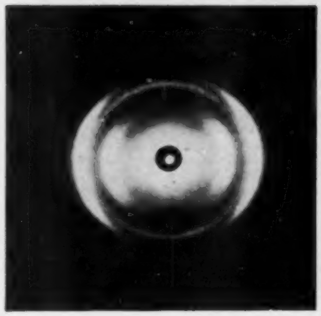

Fig. 12. X-ray diffraction pattern of a cotton fiber recorded by photography. Pictures such as this permit studies to be made of the molecular structure of textile fibers. Illustration by Courtesy of American Viscose Corp.

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LETTER TO THE EDITOR

Dear Sir:

For a number of years I have been particularly interested in the application of sensitometry in the solution of practical photographic problems. It seems to me that photographers generally are just about ready to take up this subject seriously, thanks to such publications as PHOTOGRAPHIC SCIENCE AND TECHNIQUE. Unfortunately, sensitometry in its pure and unadultered form is almost too much for most photographers, and for that matter, for most photographic writers. I often think of the address given at the convention of the Biological Photographic Assn. in Cleveland several years ago. The speaker tried to describe sensitometry but became so involved that he had to give up and never finished it. The subject is just too much for one article or one address, yet a segment means very little by itself.

It seems to me that what we need today is a new textbook which might be called "Photographic Engineering," not only for photographers, but as a reference for scientific workers who are using photography, and for business administrators who are considering the use of photography. I have been told by instructors in schools of photography that they would like to teach along these lines but there is no textbook. As soon as a photographer becomes responsible for a large scale photographic operation, he requires a great deal of information that can never be acquired in becoming a skilful photographic craftsman—the calculation of electrical requirements, water flow, filtration, heating, refrigeration and temperature control, the maintenance of automatic machines, illumination, image permanency, replenishment and circulation of large volumes of solution, materials for construction, modification of optical apparatus and so on. For a long time I have been working on such a project, but it presents many problems which are not easy to resolve. If you should feel like making any suggestions I would be most happy to hear them.

Rodger J. Ross
Bogota, Colombia

BOOKS RECEIVED

PROCEEDINGS OF THE LONDON CONFERENCE ON OPTICAL INSTRUMENTS 1950. John Wiley & Sons, Inc., New York 16, N. Y. Published March 15, 1952, 264 pages, $7.00.

Twenty-one papers that were presented at the Imperial College in London, July 19 to 26, 1950, are published here. The subjects discussed have been restricted by the organizing committee to deal with actual instruments, avoiding purely theoretical questions. Consequently the subjects are both timely and practical.

Of particular interest to photographic workers are three papers in the field of photographic and projection lenses. R. Kingslake deals with *Some Recent Developments in Photographic Objectives.* He discusses both design and materials, including High-Index glasses and plastic materials and deals with surface coatings and photometric aperture calibration. A selected bibliography is given.

H. H. Hopkins, in *A Class of Symmetrical Systems of Variable Power*, deals with the so-called "zoom" or vari-focal lenses in an historical review. The new symmetrical systems of variable power using Gaussian optics are particularly cited.

An f/1 aperture lens intended primarily for radiology is described by A. Warmisham in *A New High Aperture Photographic Objective having a Spherical Field.* The influence of the Schmidt objective on contemporary lens design is acknowledged.

THE USE OF PHOTOGRAPHY IN TELEVISION

Herbert Barnett* and Skipwith W. Athey†

ABSTRACT

The extensive uses of photography in television are described. Motion picture photography is widely represented; applications include standard feature films, films made specifically for television, films carrying commercial messages, films for integration with live sequences, and films for background projection. Still photography is represented by slides and "opaques" (prints) for commercial messages, for titles, and for special effects, as well as scenic studies for the designer. Estimates are given of the volume of use of photographic materials.

Television and photography are sister arts in both of which "pictures" are "taken." Technically, the only differences between the two lie in what happens to the pictures after they are taken, but this technical distinction belies the real closeness of their relationship. On a trip through a large television studio, one would see many scenes reminiscent of a motion picture studio, many photographic techniques in active use, and many other results of the use of photography. In order to discuss the connection between television and photography, this paper organizes the use of photography in television under three main headings. Photography in the live television studio is examined first; then photography in the telecinė or film and slide studio; and thirdly, photography in the television network. It will be noted that photography fits indirectly into television in some ways which do not fall precisely under these three headings.

The Live Television Studio

The visitor to a large live television studio while it is being used for rehearsal notices upon entering that, although much of what is going on seems to be very similar to what goes on in the motion picture studio, there are definite differences. He would probably see several different sets placed around the studio, each individually illuminated by relatively low-placed lighting units. The majority of these lighting units would contain fluorescent lamps, something seldom, if ever, seen in a motion picture studio.

Since there were once no television lighting experts, the first television lighting people immigrated from many other fields. Most of these early lighting people and many of those who survive today in television work were motion picture cameramen and lighting men. Those who survive were able to develop from photographic methods a working technique modified by television's peculiar requirements.

The television system can actually handle at the camera an extremely wide range of brightness in the scene being televised. This "handling" does not mean that under these circumstances television necessarily produces a good picture. Experience has shown that, if a television scene is so lighted that a reasonable range of contrasts is present, limiting the total gamut of brightness from the brightest part of the scene to the dimmest, the television system can work at its best. Although a wider range of overall brightness can be tolerated, unsatisfactory and variable pictures are apt to result. The television lighting man, therefore, has to scale down to a narrow brightness range illumination that the motion picture lighting man can afford to use with impunity. In addition, the non-stop nature of television production makes careful, precise, placement of lighting units, such as can be done in regular motion picture production, essentially impossible. In motion picture production, for example, lights used for filling the shadows produced by the key or motivating lights, are placed low and almost in front of the camera and barely out of its view. With television's mobility, there is no opportunity to stop and take these lights away as the camera moves around. Therefore, a modified form of lighting has been worked out in which a general or "base" light is thrown at a relatively low angle over the entire scene. This base light enables the camera to "see its way around" the studio and to give approximately correct basic exposure to all parts of the scene. Lights to give expression and interest to the scene, such as key lights and back lights, are superimposed on the base light. It is impossible to get as interesting effects when the fill light cannot be precisely controlled, but the base-light compromise is reasonably satisfactory for most television shows.

The actual units used in television lighting are in some cases identical to those of the motion picture industry. However, television's requirement for large uniformly-illuminated areas, because of the movement from place-to-place within the scene and from scene to scene, have resulted in the widespread use of fluorescent lamps. With incandescent lamps illuminating large areas to high brightness, it is difficult to get rid of the heat from the lamps. Fluorescent lamps have the double advantage that they actually produce much less total heat for the same amount of illumination, and in addition; the subjective feeling of heat from the fluorescent lamp is considerably lower than that from incandescent lamps by an amount greater than the actual difference in total heat produced. The conditions under which the actor works are thus considerably improved with fluorescent lamps. Refinements of lighting techniques are, however, not as easily achieved with the large-source fluorescent lamps as with multiple banks of

* General Precision Equipment Corporation. 92 Gold Street, New York, N. Y. Presented at the PSA National Convention, New York, N. Y., 13 August 1952, as part of the Technical Division Symposium on Photography in Engineering and Science. Received 18 August 1952.

† General Precision Laboratory. 63 Bedford Road, Pleasantville, New York.

individual incandescent lamps. The use of the standard motion picture "juniors" and "seniors," that is 2,000- and 5,000-Watt Fresnel spotlights is, therefore, quite widespread in television production. These conventional motion picture lights are used for the key or motivating lighting which gives some direction to the illumination of the scene, and they are also used for back lighting. Even with fluorescent base light, a large area with adequate key and back light may require enough incandescent lamps to make the heat load a considerable problem.

Immense indoor areas have been properly lighted and photographed, of course, by the motion picture industry many times in the past. For many of these scenes fluorescent lamps would have been useless, particularly since the lighting units had to be located far away vertically from the scene of interest. The motion picture set is in such cases illuminated with a great many incandescent or arc lighting units with tremendous attendant quantities of heat. The expense and complications introduced by these large-scale scenes have been in keeping with the scale of the particular motion picture. This kind of immense technical activity is only justified by its application to a very expensive production. So far, the television industry has not encountered productions of this scale. The limitations of the lighting techniques which television can use for large-area illumination are acceptable on the basis that any greater expenditures have not been justified by the commercial return expected from the production.

In addition to the actors, quite a few people are found in the television studio just as in the motion picture studio, but these people do not necessarily have the same jobs. In the television studio two, three, or even four cameras may be in use. A man operates a microphone boom and several men push dollies around. The solid bank of directors, assistant directors, script girls, make-up retouchers and lighting men grouped around the camera, however, are missing. Some of these people's jobs are eliminated in television because of the pace of production and the necessity of omitting some of the fine details. Others are safely caged up in a relatively distant control room away from the actual studio floor. With simplified lighting, the tremendous lighting crews required for adjustment to final perfection of the many lighting units used in motion pictures are not seen in the television studio. As a brief example of the differences and simplifications of television operations compared to motion picture operations, consider a group of people directly responsible for the handling of the camera in the two cases.

In motion picture production, if the camera is required to "dolly" in, say 20 feet, closer for a close-up after having opened with a medium shot, it is probable that three people would actually be involved with the camera itself during this dolly shot. In addition, there would, of course, be anywhere from one to six dolly pushers. We should probably find on the camera itself a camera operator panning and tilting the camera as necessary, a cameraman checking follow focus, that is setting the focus adjustment to successive marks on the lens as marked points on the floor were passed, and perhaps another assistant cameraman or the head cameraman walking alongside and by silent gestures adjusting the exact path over which the camera was moved. In television production these people are usually replaced by a single cameraman. This versatile gentleman pushes the camera around on a special dolly or pedestal, pans and tilts it, and focuses it. He usually does all three things at once. The cameraman may be helped by a couple of dolly pushers, but he is himself responsible for the motion, adjustment, and focusing of the camera. He is too busy to be very careful about precise focus while worrying about all the other movements of the camera. For this reason it is desirable in the television studio that the camera be adjusted so that it has a fair depth of focus so that errors by the cameraman may not completely ruin the picture. Use of the television camera with quite large depth of focus immediately eliminates one of the most useful techniques of the conventional motion picture. This technique is that of using limited depth of focus to produce an apparent depth or separation of planes in the final picture.

Photographic Backgrounds for Television

Tucked away in one corner of the television studio, we might very well find a large translucent motion picture screen. This screen is intended for use as it would be in motion pictures for the projection of background or process stills or motion pictures. Because of the peculiar differences in number of frames per second of motion pictures and television, the projection of motion picture backgrounds in television is not very highly developed. It will, however, shortly become of considerably greater importance as the problems of this process are solved. An extremely high-intensity projector is necessary for either still or motion picture backgrounds. Particularly with motion pictures, it is necessary to comply with complex fire regulations in the use of an arc-lamp motion picture projector in the middle of the studio building. Since 35mm background movies are to be preferred because of more light and better picture quality, the background projector operator usually finds himself in a hermetically sealed miniature booth on wheels with automatic fire shutters. This booth is designed so that there is room for the projector, one small projectionist, and a large hot arc lamp.

Motion Picture Inserts

If we were present at a rehearsal or performance of an important commercial show, or dramatic program, sustaining or commercial, it is probable that, at various times during the program, activity in the studio would suddenly come to a complete halt for a brief period. Alternately, we might suddenly observe a tremendous frantic increase in activity as cameras, actors, and stagehands scurried around the place rearranging the studio and not being too careful about noise and confusion. Either of these symptoms indicate that the functions of the studio are temporarily suspended while a film or slide or alternate studio is in use. Perhaps the most interesting of these circumstances is that of the use of integrated film.

Such a film may be used to permit the program to leave the studio and include outside scenes which would be impossible to televise directly at the time and place that the main program must occur. For example, the

hero of a television story may be seen to put on his hat and coat and walk out the front door of an interior set. As the door closes behind him, the film is started. It is taken from outside the house and shows him closing the front door behind him and starting on down the street. His activities while outside the house are covered by the film, and when he finally goes into another building, the interior action is picked up by a live television camera in another set. During the running of this film the actor is able to move to the second set and the cameras in the television studio can be moved to televise the new set. Film integrated in this manner is actually televised over a film camera chain in a separate studio.

Commercial Motion Pictures

Another cause for one of the sudden sensations of activity in the studio might be that of the televising of a commercial message. This commercial might originate from a separate live studio in which the commercial portion of the program has been individually rehearsed. However, it may also come from a separate film studio, as almost all programs use one or another form of film as part of the commercial identification. If the film is not in the form of a specific advertisement, it may be a standardized "format" informing the audience at the opening who is paying for the program, and reminding them at the end of the program of the same thing. Of course, these films which appear to interrupt the activity of the live studio must be prepared and photographed by someone, and this is another important use of photography in television.

Photography Aids Set Design

Although its contribution may not be visible as one looks around a television studio, photography is, nevertheless, a valuable aid to the scenic part of television. As in the motion picture, still photography is an important tool in the planning of realistic settings. For a dramatic production which takes place entirely in the studio, and which may require exteriors small enough to fit in the television studio, the still camera is used as a reference device. If a typical street scene is to be constructed a still photographer may be sent out to photograph a number of such scenes from life. The scenic artist can then decide from the study of the photographs just what is wanted in the studio set. The camera is particularly valuable in assuring that realistic detail is included. For integration of a motion picture of an exterior with a live studio set, the careful use of still photography permits construction of the studio set to go on simultaneously with the film production, with the assurance that the details will be made to match both cases. In an even more fundamental manner, the scenic artist usually has a large file of photographs of typical scenes, buildings, and the like from which he derives his basic ideas for practically all the sets he designs.

The Telecine or Film Studio

A teleciné studio resembles an oversized projection room with the projectors pointing in all directions, usually all running at once at all hours of the day and night, producing a fantastic amount of confusion. In the large television plant a single teleciné room may handle film for integration, commercials and other uses, as well as slides and stills for a large number of live studios. In addition, television programs entirely on film may originate entirely from the teleciné studio.

The confusion usually observable in a teleciné room is actually well organized. With as many as eight 35mm or 16mm motion picture and three or four still projectors — all capable of essentially independent operation — an elaborate system of intercommunication is needed. A particular set of projectors may be assigned to a live studio which may be several hundred feet or even several miles away from the teleciné room. Loudspeaker intercoms permit projector operators to converse with the directors at the live studios about the operation of the particular projectors assigned. The same process may be going on for different operators and different projectors in different studios all at once in one teleciné. Although only one production is apt to be on the air at once, rehearsals are going on for others at the same time, and odd moments of equipment freedom are used for previewing and timing long strings of short commercials or "plugs."

There is an alternate method of televising film in which a special projector throws a picture on a small shielded screen in the live studio. The picture is then picked up by a live studio camera. This technique has the advantage, for the small station, of avoiding the purchase of one or more special film cameras, and for the network broadcaster, of providing a flexibility and convenience in programming which is not available with a central teleciné room.

Televising Regular Motion Pictures

Feature motion pictures are made for theatre use with no intention of using them in television. In the immediate postwar period, the few feature films which could be used on television had extremely bad technical quality as viewed in the home. Because of the expense, most such feature films were transmitted from 16mm copies. These 16mm copies were what the processing laboratory would call second- or third-generation dupes. In many cases they were copies made from 16mm duplicate negatives made from release prints of the original feature film. The release prints copied were often in extremely bad condition from having been played many times in theatres. The tone range of a theatre release print on 35mm is far from optimum for further duplication. Studies have since been made of the optimum copying methods for feature films for television use, and there are many so-called secret processes for making such optimum duplicates. Without considering the details of these processes, it can be said that they produce considerably superior results when retelevised and many 16mm copies are now carefully made for television use from special duplicate negatives.

Since the beginning of television there has been a rather vocal group of people, particularly in the processing and small scale film production fields, which has insisted that television should be produced entirely from films, and that essentially no live programs are

necessary. To a certain extent, this group has seen much of its prediction come true, and the telecinė room now sees many films specifically made for television use. The production of this type of film has been encouraged by the expense and rather low quality of the only other methods available (until recently) for the distribution of TV programs. The television sponsor or producer who distributes his show to 15, 20, 30, or even 50 different stations, considers that the audiences of these stations should see a production of technical quality equivalent to the original live show. By making film for *all* stations including the one which would under normal circumstances televise the live show the producer can guarantee that every station receives a program of the same technical quality.

Production of Films for Television

It was realized from the beginning that conventional motion picture methods would be entirely too expensive for the production of films for television. From this realization has come the adaptation of the more economical methods of television production to film production. Intensive rehearsal in advance, the use of several cameras, editing at the time of production, and the general technique of photographing as much of the entire show at one continuous session as possible, are all methods which have been carried over from television to motion pictures for television. Whatever the method, the production of fifteen minute, half hour, and even one-hour films for television is now a very large business. It is not an entirely lucrative business. A great many producers with one or two cameras, one or two cameramen, and an empty barn have attempted to make a quick million dollars from such films. Very few of these operators have survived. There are, however, quite a few successful producers of films made specifically for television. Their output is in the form of single films or series for 13, 26, 39, or 52 weeks fitted to the broadcasters' yearly schedule.

In actual numbers, the telecinė room handles more film commercials than any other form of film. By "film commercials" for television, is meant the relatively brief sponsors' messages which begin, end, or fill the middle of television shows, as well as the so-called spot announcements or plugs which fit between two successive full-length programs. The larger, more expensive, national television shows use a great deal of live commercial material, that is, the equipment or device being advertised is demonstrated either in the studio in which the rest of the show takes place or in a separate commercial studio. But even such programs use films for opening and closing sequences which announce the name of the manufacturer and his product. Many of the medium-size television shows use commercials entirely on film, sometimes with live verbal commentary, but often with the sound also on film. Such film may be live motion pictures or animation. Some products have become inextricably connected with the personalized and animated devices which are used in the commercials. Since many television stations, particularly the smaller ones, keep themselves alive with the spot commercials between programs, the number and commercial importance of such spot films is tremendous. The production of spot films is a field in which many extremely small motion picture producing outfits have been started. It is not necessary to have a large amount of equipment, and many such producers are one-man operations.

Television of Still Pictures

In addition to 16mm and 35mm motion picture films, a telecinė room handles still pictures. These may be in various forms. The most common forms are the standard 2" × 2" slide, which is actually a double silent 35mm frame, and approximately 4" × 5" opaque pictures. Some studios use larger and smaller opaques and others also use standard 3¼" × 4" lantern slides. The bulk of the still pictures televised outside the live studio, however, are in the form of 2" × 2" slides or 4" × 5" opaques. Although some slide projectors have been made specifically for television, the 2" × 2" slide ends up more often than not in a slide projector essentially identical with one you might find in your own home. Some stations which prefer remote control operation have wheel-type or bin-type automatic slide changers for 2" × 2" slides. A practice which is just coming into use and which may become more and more widespread is the use of a flying spot scanner type of television camera for the televising of slides. The flying spot scanner should be capable of considerably superior reproduction of 2" × 2" slides, but this technique is not at present applicable to motion pictures. Improvements in the usage of the standard iconoscope camera in the telecinė room indicate, however, that it may take a new lease on life and compete directly in quality with the more complex flying spot scanner.

Most television stations have a device which they refer to as a "balop." This peculiar name is an abbreviation of the Bausch & Lomb Optical Company trade name "Balopticán" for a range of slide projectors they make. In the days when the television station built or modified most of its own equipment, a combination of one or two Balopticans was used for slide or opaque projection and the abbreviation, "balop," therefore, has gotten into wide use. Other companies now manufacture commercial slide and opaque projectors specifically for television use usually, however, managing to maintain some of the sound of the original "balop" in the name. A typical device of this type takes 4" × 5" opaque slides mounted on long strips of metal, so arranged that the slides may be advanced one after another into the field of view of the projector. Such a projector has two slide holders and the operator may dissolve from one to the other by changing the brightness of the illumination on the slide. The operation of one of these so-called balops is a highly complex and rather nerve racking job. The operator hears over headphones directions from the program director as to when to change slides mechanically and when to dissolve from one to the other. The process of keeping several long strings of slides straight is confusing to say the least. This is one of the jobs in the television studio which requires constant rotation of personnel to preserve nerves.

Size 2" × 2" television slides are, of course, produced by photographic processes. The subject material may be original photographs with additional advertising or descriptive material added by an artist, or they may

be from original art work. Opaque slides are very often direct art work done on the 4" × 5" format which will be televised. Opaques may also be photographed with or without additional art work, including news photographs and advertising material. In come cases the long format of several separate slides mounted on one metal strip may be replaced by a long continuous cartoon or similar piece of art work which can be advanced slowly in the slide holder in order to give an elementary kind of animation. The majority of the opaque slides are limited to such mundane subjects as the opening and closing titles of a live or film program.

Television Recordings

One type of film material which is of major importance in many telecine rooms and which has not been mentioned so far is the television recording. Television recordings are used by the networks in three major ways. First, they are used to provide program service to stations which are not connected to television networks. Second, they are used to permit distribution of low-cost and sustaining programs at times which may be selected at will by affiliated stations rather than arriving on some rigid schedule from the network production center, and thirdly, they are used to adjust for the time delay in traveling across the country because of the various time zones and the use of daylight saving time in some states while it is not used in others. Related to this last use is the rearrangement of program schedules as produced at major east and west coast program centers to take care of the fact that not all networks can always send all the programs they want in all directions at once on the available telephone lines.

For non-connected stations the usual practice, particularly with fairly timely commercial programs, is to make a recording and to prepare anywhere from five to thirty or even forty prints of this recording. These are then distributed in a more or less radial manner to the non-connected stations. For such multiple prints, it is apparent that 16mm film permits a considerable saving over 35mm film. For the relatively brief sustaining, that is, unsponsored, programs which the affiliated station may want to scatter through its daily program schedule, it is quite common to produce a relatively small number of prints, perhaps 5, and to "bicycle" them around from station-to-station. These programs have no particular time or commercial value, and a single print may travel to six or even ten stations over a period of weeks before it finally has been used by all affiliates who want it.

For program delay because of time differences and for surmounting the difficulties of unavailability of network facilities, it is a quite common practice to use 35mm recordings which are used only once and are retelevised directly from the negative. This has particular value because it appears that, with normally-operated film cameras, the negative televises somewhat better than the print. This contributes to the desired high pictorial quality of programs which normally would be important enough to send across country. In addition, the fact that time is not consumed for making a print saves valuable time when the delay is as short as three hours or even one hour.

The process of recording and reproducing television pictures has been described by many names, among which are "television recording," "video recording," "kinescope recording," (and its abbreviation "kine-recording," or just plain "kinescoping") "teletranscription" and "television transcription" as well as a number of other trade names. In the present state of the art, the only method available for reasonably high-quality television recording consists in photographing a high-quality television monitor tube, thereby producing a motion picture from the television program. The process of recording is in some ways complex; in other ways relatively simple. It has the tremendous advantage of producing the record in a form in which any television station may reproduce it. That is, the fact that it produces a motion picture makes this form of recording available to any television station, since the first piece of equipment that a television station needs to get pictures on the air is some kind of a film-televising device. Although other forms of television recording have been proposed, using film or magnetic tape, the basic fact as of now is that television recording is a form of motion picture photography. It is a very peculiar form of motion picture photography by conventional motion picture standards, but, nevertheless, one which has in one form or another most of the worst problems of conventional motion picture photography. Television recordings, because they are recordings, must be made with high consistency. That is, if there is anything wrong with the final recording, it is usually considered in broadcasting that the fault must be chargeable to the original program production and the recording process is assumed to be consistent and routine. Since, in addition, television recordings when reproduced have passed through the original television system, through the motion picture process and once again through the television system, the increase in noise or granularity, the decrease in sharpness, and the losses in tone scale which are inherent in each of these processes are accumulated in the final result. Since the television recording competes in the reproducing television station with live television programs and films made specifically for television, the television recording process is hard put to produce a picture which, having passed through three processes, can compete with a picture which has passed through only one or two processes.

It is probable that the television recording process employs more film than any other portion of television. A reasonable estimate of the total footage of 16mm film used for television recording by the major networks is something like $^2/_3$ of a billion feet per year. The major networks are now the largest customers of the film manufacturers for 16mm film. The bulk of television recording is done on 16mm film largely because of cost, although it is generallly agreed that 35mm film, simply because it has four times the available picture area, does produce a higher quality motion picture or television recording than does 16mm film. However, since $^2/_3$ of a billion feet of 16mm film is equivalent to $1^1/_3$ billion feet of 35mm film, economics would indicate immediately that the use of 16mm film tends to be more widespread than that of 35mm.

Making Television Recordings

Although specific techniques differ from station to station and from network to network, the basic method of making television recordings is the same in all cases. The process may be outlined as follows:

The standard motion picture is projected at the rate of 24 frames per second with each frame visible twice during the projection cycle. A television picture consists of 60 interlaced fields making up 30 frames or complete pictures per second. Some trick is necessary to transform a 30 frame-per-second television picture into a 24 frame-per-second motion picture. The method currently used, the subject of a patent by Epstein of RCA, operates by exposing two fields or one complete frame of the television picture on one frame of motion picture film. During the next half-field of the television picture, the shutter of the motion picture camera is closed, either effectively by turning off the cathode ray tube being photographed or by actually closing a mechanical shutter, and the motion picture film is advanced one frame. In the middle of this particular field of the television picture, the shutter is opened again and the last half of this field, the entire next field, and the first half of the next field are all recorded on the motion picture film. During the next half-field of the television picture the shutter is closed and the film is advanced again. The process is now back to where it started.

Two television frames or four fields of exposure plus two half-fields for pull-down have occurred since the cycle started. Since the fields each last $^1/_{60}$ of a second, $5 \times {}^1/_{60}$ or $^1/_{12}$ of a second has taken place since the beginning of the cycle. During this same $^1/_{12}$ of a second the motion picture film has been exposed on two successive frames and is ready to expose another frame. At the rate of 24 frames per second, this part of motion picture process takes just $^1/_{12}$ of a second, and it is apparent that the timing of the television picture has been fitted to that of the motion picture. Two half-fields have been lost in the process and this contributes a small amount to picture degradation. More important, the starting of the motion picture exposure in the middle of the field and ending it in the middle of another field requires that the timing and mechanical adjustment of the stop and start of exposure must be very precise. If this is not the case, a "join-up" or "splice" or "shutter-bar" will be apparent where the two ends of the different fields overlap or fail to meet properly. The optics, mechanics, and electronics of the television recording process, therefore, have to be quite precise. The extremely short time allowed for pull-down of the film in the camera, that is, $^1/_{120}$ of a second, also adds to the complications. A factor which had been ignored early in the process is that of operating any type of intermittent film moving device for one half hour continuously with raw film. The combination of fast pulldown and the long period of operation resulted in collection of tremendous amounts of film dust which had been negligible in previous motion picture operations. Because of its commercial importance television recording was in full-scale use long before the difficulties raised by the nature of the process had been cleared up on anything approaching a routine basis.

Since a television recording, when reproduced, should ideally be indistinguishable from a live television pickup, a careful balance must be made between economics and the highest possible sharpness, fidelity of tone gradation, and lack of grain or noise. Either a master positive or variable density sound recording film is usually used as the negative material. These films have the advantages of relatively high resolving power and cost of the order of 1¢ per 16mm foot compared to the 4¢ a 16mm foot cost of most negative materials for direct photography. These special films require a relatively bright picture for adequate exposure. An intense blue phosphor called the P11 is usually used on the recording monitor tube.

Since what is wanted in television recording is something that will reproduce as well as possible on the television system, the recording itself is not necessarily a very attractive motion picture film. The adjustment of exposure and processing is, therefore, not made entirely by visible adjustment for a pleasing picture either on the monitor or on the film. Although a qualified type of judgement was originally used by many makers of television recordings, present practices usually include some type of overall system brightness characteristic measurement for the determination and control of exposure and processing. In one method, an overall measurement is made from the video voltage into the recording unit to the final density on the developed video-recording negative. Separate sensitometric exposures are made on the recording negative for this test in order to permit measurement and control of the processing. Density measurements are made on the negative and compensated for whatever peculiarities of processing are shown by the separate sensitometric tests. The exposure, which means the settings of the brightness and contrast controls on recording monitor, is then adjusted on the basis of these tests. Because each monitor tube has its own individual characteristics and since minor changes from batch to batch in film characteristics are apparent when tests of this precision are made, continuous follow-up is necessary on a day-to-day routine basis to insure that recordings of uniform quality are produced by each television recording unit. From two to eight television recording units may be grouped together in one recording plant, particularly in a network program production center. Since all programs are usually recorded in duplicate for safety, and since the maximum length of continuous recording possible with a single unit is usually limited to one half hour by the 1200-ft rolls of film used, extra-long programs or those during which failure of part of the equipment occurs, require that the recordings from one unit of the recording equipment match those from any other unit. Maintenance of this matching is perhaps the leading television recording problem.

The sound which accompanies the television picture may be recorded on film at the same time and in the same unit as the picture recording. A separate film may be used also to record the sound, giving what is known as "double-system" recording. The sound recording under these circumstances is usually made in duplicate, either on the second film or on a synchronized magnetic tape. The use of tape permits great economies, since the duplicate or "safety" tape may be erased and reused if the original recording is satisfactory. If all the recording is done on tape, the tape may be continuously reused without any material cost except for one re-recorded film negative per reel.

Intermediate-film Record for Theatre Television

Another important use of television recording is in the so-called intermediate-film theatre television system. In this process, a television signal arriving at a theatre is recorded on a motion picture film as a positive picture. This film is developed and dried in a very short period of time and is fed directly into a motion picture projector. The film is projected in the normal way by the motion picture projector. This rather round-about method of getting a television picture onto a large screen has the advantage over any direct-projection television system of permitting the use of the normal light source and optics of the standard motion picture projector. Assuming that the recording and developing process can be accomplished, this system produces on the motion picture screen without difficulty a picture as large and as bright as a standard motion picture. Direct-projection television systems must, however, continue to struggle against the low light output of television picture tubes in order even to approach the brightness of the standard motion picture screen.

In a few cases, television recording is done on 35mm film and is used in the existing motion picture theatre projector. In other cases, the recording is done on 16mm film, and a special high-intensity 16mm projector developed for this process is used. The rapid processor produces a dry, developed film approximately 40 seconds to one minute after entry of the exposed film. Development is carried on at a high temperature, solutions are applied by specially designed spray techniques, then carefully removed, and high speed drying techniques are so worked out as to avoid damage to the film. The recording is made from a negative image on the cathode-ray monitor tube, using film of the type regularly used to produce release prints in theatres. In some experiments, sound is recorded by direct-positive variable-density toe recording, employing a specially-shaped modulating mask, and the sound is developed along with the picture. The design of this kind of equipment is complicated by the fact that it must be operated by the regular projection-room personnel, and must conform to the usually stringent requirements of any device that is to be installed in a theatre projection room. Any special tests for exact control of the sensitometry of developing and the like must be unnecessary beyond the simplest of routine maintenance, since there is no opportunity in a motion picture projection room for such details. The performance of such equipment must conform to as high standards of consistency as are required in network television broadcasting, and at the same time, the operation must be extremely simple.

The rapid processor used in the theatre film television system just discussed has application in the network television center as well. Use of such rapid processors is becoming greater for the specialized service of short-delay recordings. Such recordings are usually made by the direct-positive method, that is, by photographing a negative monitor tube image onto positive film. At its best, the quality of such a direct-positive recording can be quite superior to that of a negative-positive film recording because of the elimination of the losses in the printing process. In addition, such a single-film system has tremendous advantages in time-saving for providing relatively short program delays in the network distribution center.

Since television is a new art with economic factors still in a state of flux and with techniques in a painful process of development by trial and error, anyone who ventures into the television business from another field is certain to face a great deal of confusion. If this adventurer is a still photographer, he will find his art used in many ways in television, some of them direct, some of them indirect. If he assumes that he may make pictures for television in much the same way that he has made pictures for other purposes in the past, he will have trouble with the deceptive similarity of television to other fields of photography in some respects, and its complete difference in other respects. The motion picture photographer will encounter the same kinds of problems. He will find fairly straightforward film production techniques being used for films for television, modified techniques being used for commercials, and a bewilderingly different use of motion picture photography in television recording. He will be confused, for example, by the basic problem of whether a television recordist is a photographer, a broadcast engineer, a projectionist, or a mixture of all of these men.

In one sense, television lies in a No-Man's land between radio and motion pictures. To operate usefully in many of the technical aspects of television, a basic knowledge of the fields of photography and communications is really necessary. The photographer who understands his own art from a technical and artistic point of view, who develops a certain flexibility of viewpoint, and who is willing, within reasonable limitations, to believe what the communications technicians tell him are limitations of the art, is an extremely useful person in the television field. However, the photographer who goes into television work fully convinced that television is just like photography and who cannot adjust to the actual differences in television technique, is perhaps the most useless person around the television plant. Television and photography are sister arts and a dual respect for individual peculiarities within the family is necessary for mutual progress.

A new journal. ***Die Farbe,*** edited by Dr. Ing. Manfred Richter in Berlin and published in Wiesbaden by the Verlag für Angewandte Wissenschaften GMBH, has been announced. The preface to the first edition speaks of the intent to publish papers "on the different problems of Color Science, such as color vision and its testing, color matching, light and color, evaluation of fastness, color photography, television and reproduction, color psychology and color conditioning, color standardization work and color nomenclature and terminology". Short abstracts in both German and English will inform the reader about the essential content of each article. Subscriptions cost 42 marks, in advance, for one volume of six quarterly issues, with postage additional.

PHOTOGRAPHING HIGH-SPEED CATHODE-RAY OSCILLOSCOPE TRACES

Harold J. Peake*

ABSTRACT

To meet the need for increased photographic sensitivity of cathode-ray oscilloscope recording systems, a study has been made of camera design, film types, and processing methods to determine the best combination. With the chosen combination, recordings have been made showing a rate of change of voltage of 3×10^{12} volts per second. The corresponding trace velocity on the oscilloscope screen was 13,000 inches per microsecond, well above the free-space velocity of light.

RECENT ADVANCES in the electronics art have resulted in or depended upon the means for easily generating, displaying, and recording transient voltages with ever-faster rates of change of voltage. In many cases the transient voltage is generated by a natural physical phenomenon, such as the output from a phototube illuminated by a scintillating medium. In other cases the transient must be artificially generated, say by gaseous switch tubes in appropriate circuits. In either event, there remains the need for displaying and recording faithfully the waveforms of electrical events. This need exists in the fields of electricity, electronics, and nucleonics wherein display and recording for further analysis are prerequisite to progress.

Probably the most satisfactory means for obtaining permanent records of electrical phenomena is the photography of the display on a cathode-ray-tube screen. In this report, only "external" photography is considered; i.e., only the photography of the actual light output of a cathode-ray-tube phosphor. "Internal" photography, wherein the beam of a high-voltage (50-kilovolt or higher), cold-cathode demountable tube is made to impinge directly upon the photographic emulsion, has been used in some work.[1] The bulk and complexity of the demountable oscilloscopes, including necessarily a vacuum pumping system and a high-current high-voltage supply, place them out of the class of ordinary laboratory or field instruments. Hence, an attempt has been made to exploit the use of more common devices (sealed-off cathode-ray tube, low-current high-voltage supply, etc.) in order to provide a simple, inexpensive, rapid means for recording fast transients.

The work of the investigation of transient recording may be divided into two different categories: (a) electronics and (b) photographic. Obviously, however, the two are not exclusive. The electronics problem (which is not considered here) involves the choice of cathode-ray-tube type and operating conditions as well as the provision of the necessary auxiliaries such as the intensifier, low- and high-voltage power supplies, etc. The photographic problem includes camera design, choice of emulsion type, and evolution of processing technique. The chief mutual consideration is the choice of cathode-ray-tube phosphor (and, hence the spectral light output) and the spectral sensitivity of the photographic emulsion.

The Oscilloscope Camera

Lens Comparisons. The main criteria for the choice of an oscilloscope camera lens include high effective lens speed (large aperture, low reflectivity), essentially flat field of view, and minimized barrel vignetting

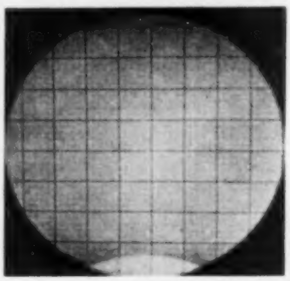

Fig. 1. Flatness-of-field test of the Wray f/1.0 lens at a 4:1 copy ratio.

(decrease in light transmission near the edge of the lens compared to the transmission in the center). In designing the camera used in the work reported here, four different lenses were tested. Of the lenses considered, only the Wray f/1.0, 2-inch lens was designed to have a flat field when used for copy work. In fact, this lens is designed to be used at the specific copy ratio of 4 to 1. Hence, the Wray lens, fitted with the Wollensak Alphax shutter, was incorporated in the final scope camera design. Figure 1 is a photograph of a sheet of rectangular coordinate paper taken with the Wray f/1.0 lens at a 4-to-1 copy ratio to check the flatness of field.

Camera Design. The camera used to record the oscilloscope traces for this investigation was the Edgerton, Germeshusen, & Grier, Inc. Type 3114 Scope Camera. A general view of the camera is shown in Figure 2. In Figure 3 the camera proper has been removed from the

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The material contained in this paper is included in a thesis to be submitted to the University of Maryland, College Park, Maryland, in partial fulfillment of the requirements for the master of science degree.

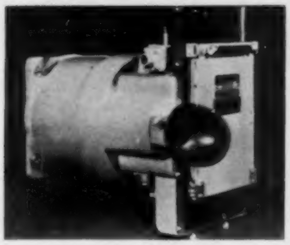

Fig. 2. Edgerton, Germeshausen, & Grier, Inc. Type 3114 Scope Camera used in the investigation.

barrel-type body. The camera body fastens to an oscilloscope by means of metal clips which engage studs mounted on the oscilloscope front panel.

The Type 3114 camera has the Wray f/1.0, 2-inch, 4-to-1 copy ratio lens with the Wollensak Alphax shutter providing time, bulb, and exposure times ranging from one to 1/100 second. The iris diaphragm control (allowing an f/2.8 minimum aperture) and the shutter speed are adjustable by means of graduated rods protruding from the camera housing. Flash synchronizing contacts (X, or zero-delay, type) are wired to a cable connector on the camera to provide synchronized triggering of external devices or circuits when desired.

To take advantage of the wide variety of emulsion types available on sheet film, the camera takes 4 × 5 inch Graphic-type film holders. Since the lens produces a one-inch diameter circular field in the film plane, the back of the camera is positionable, permitting five exposures on a single sheet of film. Each exposure or frame may be numbered while the frame is in position behind the lens. There is mounted on the outside of the camera housing a Veeder counter, the setting of which is duplicated on an identical counter inside the camera. Pressing a push-button illuminates the inside counter (by means of a self-contained battery and flashlight bulbs), the image of which is focused on the film plane alongside the frame in position behind the f/1.0 lens.

Other features of the camera include a viewing port with a hinged light-tight cover and rubber eye cup to permit viewing the oscilloscope screen with the camera in place; and 24-volt d-c solenoid actuation of the shutter release for remote operation.

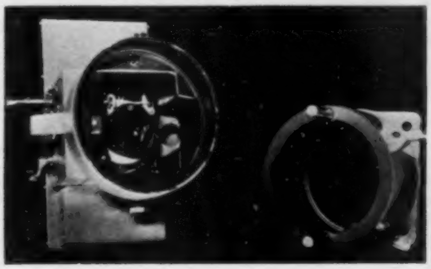

Fig. 3. Type 3114 Scope Camera, removed from camera barrel which engages the oscilloscope front panel.

Focusing. Focusing of the Type 3114 camera is accomplished by moving the camera along the two guide rods secured to the camera barrel. Thus the lens-to-object distance is adjusted. The back focus or lens-to-image distance, is automatically held constant. This is done by extending the lens-mount tube the correct distance beyond the back element of the lens so the lens tube contacts the sheet film. To allow for variations in the dimensions of film holders the lens mount is movable along the lens axis, the mount being spring loaded to assure intimate contact with the film. A lever on the camera provides a means for manually positioning the lens assembly when removing a dark slide or when moving the back to a new frame position.

Since the film is nominally $12^{1}/_{2}$ inches from the cathode-ray-tube screen and since the aperture (f/1.0) is large, focusing becomes quite critical. It is extremely difficult to focus a weak, non-recurrent trace on a ground-glass screen, so recourse is made to a more satisfactory means of focusing. The focusing device shown in Figure 4 is made by mounting four 6.3-volt lamps in a modified Graphic 4 × 5 inch film holder. These lamps surround a circular hole cut through the center partition of the holder. This hole is covered by a piece of ground glass on one side and by a transparency of a sheet of rectangular coordinate paper on the other side. This entire assembly is placed in the camera back, just as is an ordinary loaded film holder, voltage is applied to the lamps and, with the shutter open, the image of the coordinate paper is projected onto the cathode-ray-tube screen. By viewing the projected image through the camera viewing port, the camera may be focused quite critically. This method of focusing has the outstanding advantages of ease of accomplishment, even in a well-lighted room, and of requiring no changes in oscilloscope adjustment or operation.

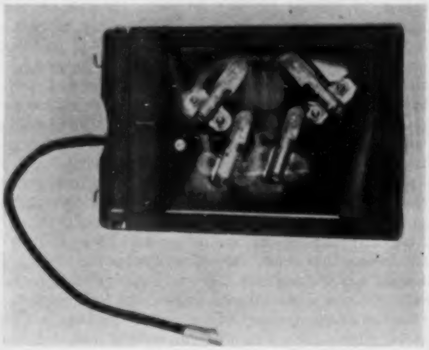

Fig. 4. Focusing aid for Type 3114 Camera which projects an illuminated line image, lying in the focal plane of a film holder, through the camera lens onto the screen of the cathode-ray tube.

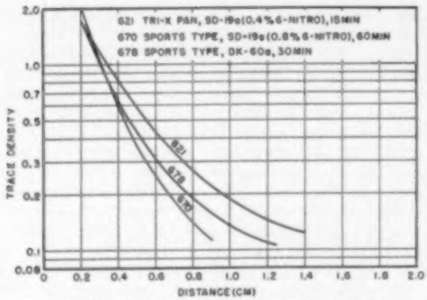

Fig. 5. Method of selection of film-development combination. Higher trace *density* measured at a given *distance* along the trace axis indicates a higher effective emulsion speed.

Tests of Films and Processing Techniques

The problem of photographically recording very weak (very high spot velocity) cathode-ray-tube traces is the problem of obtaining the highest possible effective emulsion speed commensurate with good resolution. Using a cathode-ray tube with the type P-11 phosphor, the most highly actinic light producer of the phosphors available, the problem is that of handling a serious underexposure to light predominantly in the blue region. Maximum radiant output from a P-11 screen is produced at a wavelength of 4600 Angstroms. The light-persistence characteristic of this phosphor is such that the light output decays to one per cent of the maximum within one millisecond after removal of the excitation. The effective exposure time for a single transient screen excitation is about 0.2 millisecond. Thus it may be that, due to this short exposure time, some loss in film emulsion speed is suffered due to reciprocity-law failure;[2] however, no evidence of such failure has been noted.

Films and Development. To discover the best combination of film and processing technique for the trace-photography application, a study of numerous combinations was made. First, the films listed below were subjected to identical exposures by means of transient traces on the DuMont type K1056-P11 cathode-ray tube:

a. Ansco Isopan
b. Ansco Superpan Press
c. Ansco Triple S Ortho
d. Eastman Super Panchro-Press, Type B
e. Eastman Portrait Panchromatic
f. Eastman Panatomic-X
g. Eastman Tri-X Panchromatic
h. Eastman Super-XX Panchromatic
i. Eastman Super Panchro-Press, Sports Type
j. Eastman Ortho-X
k. Eastman Super-Ortho Press
l. du Pont Type 428

Each of these films was developed in each of the following Eastman developers (at 20C) for a time sufficient to produce a background density of 0.3 to 0.4:

a.) D-8	e.) SD-19a[3]
b.) D-11	f.) DK-60a
c.) DK-15	g.) X-ray
d.) D-19	

By visual examination of the character of the negatives obtained, and with the aid of density measurements made on a microdensitometer, a selection process was carried out to determine the best combination of film type, developer, and development time. For the conditions imposed here, the optimum combination is Eastman Super Panchro-Press, Sports Type film developed in Eastman DK-60a developer for 25 minutes at 20C, with intermittent agitation in a sheet-film developing tank.

In addition to the film types tested above, Eastman Linagraph Pan and Linagraph Ortho types were also tried. Although these emulsions were available on a 35mm base only, the manufacturer's stated effective emulsion speeds were so high that samples were tested nonetheless. For this application, however, the Linagraph Pan film was found to have an effective speed about equal to Super-XX and the Linagraph Ortho has a speed considerably less than Super-XX Panchromatic.

Method of Selection. The selection of film and development combination was accomplished in several steps, each successive step resulting in the elimination of one or more combinations. For each step in the selection

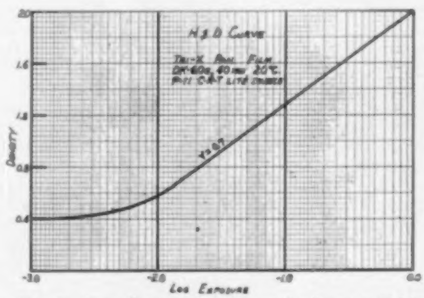

Fig. 6. Film Characteristic Curve for Eastman Tri-X Panchromatic film exposed by P-11 cathode-ray-screen illumination.

process, the procedure was to choose a few of the better film—development combinations by visual examination, then to obtain plots of recorded density versus spot position at several points along the trace by using a scanning microdensitometer. These plots gave resolution (line-width) data, an estimate of grain size and distribution, and a measure of effective film speed. Since the sweep recorded in these tests increased speed monotonically across the cathode-ray-tube screen, the effective emulsion speed is proportional to the distance along the sweep direction to the point where the trace density falls to a chosen minimum value. A sample set of density-distance curves is shown in Figure 5. These curves show an apparent superiority of Tri-X Panchromatic film developed in SD-19a; the superiority, however, is one of effective emulsion speed only, the resolution being so poor due to excessive grain size that another choice is demanded. Hence, the combination of Super-Panchro-Press, Sports Type film and DK-60a developer was chosen as best for the application in hand.

Variations. In addition to tests of developers with recommended proportions of the chemical constituents,

tests were performed using different amounts of Kodak Anti-fog No. 2 (6-nitrobenzemidazole nitrate) in SD-19a and in DK-60a. Generally speaking, the only significant result observed was the variation in time required for proper development, this time being proportional to the concentration of anti-fog material. Another test performed was extended development at low temperatures (i.e., below 20C); no significant change in the developed-out image was noted for developer temperatures down to 10C.

Pre-fogging. To secure maximum writing speeds photographic emulsions may be hypersensitized before exposure by any of several methods,[3,4] the most attractive being pre-exposure to light (pre-fogging). The pre-fogging must be done in such a way that (a) a detectable recorded density is obtained due to the pre-exposure, (b) the light is uniform over the field of view of the device used to pre-expose the film, and (c) the exposure is to a high-intensity source for a short period of time. One simple means for pre-fogging film is with a camera. Using a shutter speed of 1/100 second, Super Panchro-Press, Sports Type film was pre-exposed to a diffuse light source, the intensity of which was properly adjusted. A comparison with identically exposed film which had not been pre-fogged showed that prefogging resulted in a significant increase in the recorded trace density (above fog density) at a given trace speed. This result indicates that the effective emulsion speed is increased by proper pre-fogging.

Latensification. Latensification[3,5,6] or sensitizing subsequent to exposure and before development, can be accomplished by one of several methods, the simplest being exposure to light. Again the exposure should be uniform and just sufficient to increase slightly the background density. Latensification is more efficient if the light intensity is adjusted to allow an exposure time of 15 minutes or more. These conditions are fulfilled by placing exposed Super Panchro-Press, Sports Type film in an open film holder about 8 feet below a 10-watt lamp with a Wratten Series 3 (dark green) filter fitted into the lamp housing and a sheet of bond paper (white) over the filter. A latensification time of about 20 minutes appeared to give the maximum effective emulsion speed increase. The increase in speed obtained by latensifying was essentially the same as that produced by pre-fogging.

Fig. 7. Cathode-ray-tube trace Recording. Vertical deflection: 200-megacycle oscillator output. Horizontal deflection: pulse generator output.

Intensification. Developed-out photographic images may be intensified by treatment in a chemical intensifier. The Eastman formula for In-6,[2,7] a quinone-thiosulfate intensifier, was prepared and used to treat some negatives of cathode-ray-tube traces. For a ten-minute treatment at 20C an increase of trace density (above fog density) resulted. No loss in resolution was noted. The use of In-6 produces a reddish-brown coloration in the treated negative, but the permanency of the image is not altered.

Copying. Often it is desirable to copy original negatives of cathode-ray-tube traces. Copies may be used for extended examination and data taking, thus preserving hard-to-reproduce originals. In the interests of accuracy, the distortion of the original recording inherent in the copying process must be considered. To select a suitable copying process a negative photograph of a sheet of rectangular coordinate paper was prepared. Contact prints of this negative were made on several film types including Eastman Contrast Process, Commercial, Panatomic-X, du Pont Type 428, Ansco Isopan, and lantern slide plates. The copies were processed according to manufacturers' recommendations. By means of a coordinate-comparator microscope the distortion of the linear dimensions of the original negative present in the copies was measured. Distortions up to 1% were found, the minimum distortion of 0.04% being obtained on Ansco Isopan 4 × 5 inch sheet film.

Choice of Film and Technique

The experiments described did not reveal any cumulative action due to the use of two or more of the techniques tested for increasing effective emulsion speed. In other words, for the photography of very high-speed cathode-ray-tube traces there appears to be no advantage gained by using more than one of the speed-increasing schemes on a given recording. On the basis of the tests described here, the best choice of film and processing is as follows:

Film: Eastman Super Panchro-Press, Sports Type.

Development: 25 minutes in Eastman DK-60a developer at 20C., intermittent agitation in a cut-film tank. This development produces a chemical fog of density 0.3 to 0.4.

Pre-fogging: short exposure to incandescent or fluorescent light source of brightness sufficient to produce recorded density above fog level.

At the time of this writing, the Eastman Kodak Company is not manufacturing Super Panchro-Press, Sports Type film, having been forced by increased demand for film to reduce the number of emulsion types being produced. Until Sports Type film is again available, Eastman Tri-X Panchromatic film is the best substitute. The development time should be extended to 40 minutes. As shown in Figure 6, Tri-X Panchromatic film exposed to the light output of a P-11 cathode-ray-screen phosphor and developed as recommended here produces negatives with a background fog density of about 0.4 and a gamma of 0.7.

Sample Recordings

Whereas the maximum recordable trace velocity of a cathode-ray-tube recording system is not a measure of its capabilities compared to a different system, the

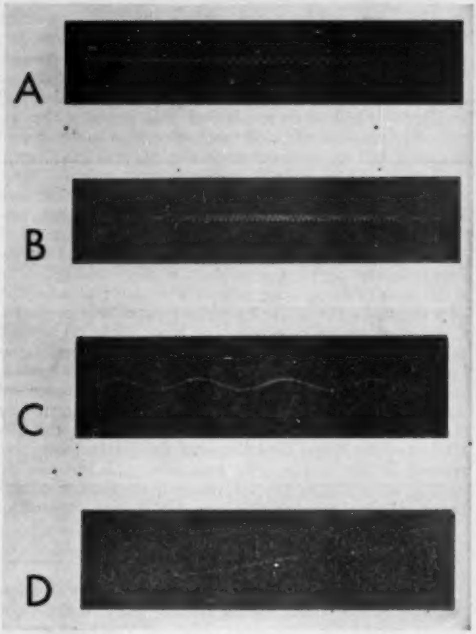

Fig. 8. A. Cathode-ray-tube trace recording. Vertical deflection: build-up of output of a 6500-megacycle pulsed magnetron. Horizontal deflection: pulse generator output.

B. Cathode-ray-tube trace recording. Vertical deflection: output of a 10,000-megacycle pulsed magnetron. Horizontal deflection: pulse generator output.

C. Cathode-ray-tube trace recording. Vertical deflection: output of a 6500-megacycle pulsed magnetron. Horizontal deflection: coaxial breakdown gap fired by pulse generator output. Rate of change of horizontal-deflection voltage: 1.5×10^{12} volts per second. Trace velocity: 6500 inches per microsecond.

D. Cathode-ray-tube recording of trace with velocity greater than velocity of light. Vertical deflection: output of a 6500-megacycle pulsed magnetron. Horizontal deflection: coaxial breakdown gap fired by pulse generator output. Rate of change of horizontal-deflection voltage: 3×10^{12} volts per second. Trace velocity: 13,000 inches per microsecond (velocity of light = 12,000 inches per microsecond).

maximum recordable velocity is a yardstick for measuring improvement of a given system. The need for high-speed trace photography arises when it is desired to record the wave-form of an electrical voltage or current which changes amplitude at a rapid rate. The actual trace velocity corresponding to any rate of signal amplitude change depends entirely upon the cathode-ray-tube design. Hence, a more realistic figure for comparing recording systems having equal resolution is the maximum recordable rate of change of applied signal. Even this basis, however, is not a completely fair one because it does not include the factor of convenience or ease with which records may be made.

All of the high-speed transient recordings shown were made on Tri-X Panchromatic film exposed in the E.G. & G. Type 3114 Scope Camera. Figure 7 and all but recording D in Figure 8 represent traces very nearly four inches long; i.e., full-screen deflections on the cathode-ray tube. On Figure 8 record D, only the one-inch center portion of the trace was successfully recorded. The transient signal is applied to the horizontal-deflection plates. The signal is generated by either a pulse generator or the combination of a pulse generator and coaxial breakdown gap. For timing purposes the output of an oscillator is applied to the vertical-deflection plates. Oscillator frequencies of 200, 6500, and 10,000 megacycles are used as noted in the figure captions.

The maximum rate of voltage change recorded (Figure 8D) is 3×10^{12} volts per second—three million volts per microsecond. The corresponding trace velocity of 13,000 inches per microsecond is in excess of the free-space velocity of light, 12,000 inches per microsecond. This trace velocity is, of course, not in violation of the relativistic increase in mass of particles moving at high velocities. The trace velocity is really a phase velocity (writing velocity), which type of velocity can and does exceed the velocity of light; e.g., phase velocity of electromagnetic waves in a waveguide. With the present equipment and technique this rate appears to be about the maximum recordable.

The comparative ease with which good-resolution records of extremely high-speed electrical phenomena may be obtained should be of considerable aid to workers in the fields of electronics, electricity, and nucleonics.

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